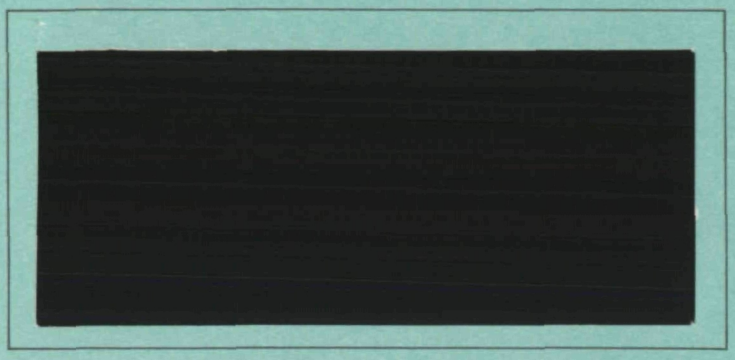

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(NASA-CR-143351) STUDY OF FEASIBILITY OF CONDUCTING MARS LIFE DETECTION EXPERIMENT IN-SITU Final Report (Biospherics, Inc.) 167 p

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Report

STUDY OF FEASIBILITY OF CONDUCTING MARS LIFE DETECTION EXPERIMENT IN SITU

FINAL REPORT

Final Program Study Report

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Prepared under Contract No. NAS2-5360

by

BIOSPHERICS INCORPORATED
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for

AMES RESEARCH CENTER

National Aeronautics and Space Administration

December 31, 1969

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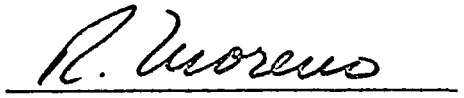

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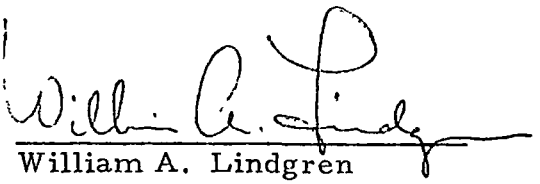

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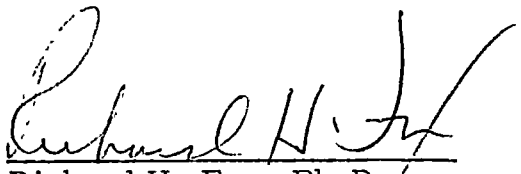

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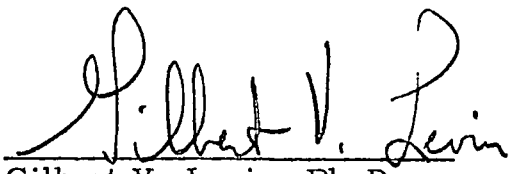

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The film sequences show several of the experiments performed in our laboratories in connection with the Feasibility Study which is the subject of this Final Report.

The first half of the film deals with Biology Program experimentation and testing, while the second half deals with Engineering Program experimentation.

Captions and charts are included as an integral part of the film, and the viewer should not experience any problem in following the presentation.

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ABSTRACT

Biospherics Incorporated performed a study under contract NAS2-5360 to determine the feasibility of conducting automated, in situ life detection experiments on Mars.

It was postulated and verified that in situ life detection experiments offer increased probability of success and greater sensitivity than do tests performed on mechanically removed samples.

A highly desirable feature of an in situ experiment is the ability to supply water to the sample in vapor and liquid form. However, this is a severe problem because of the Mars environmental conditions. Detection of labeled, metabolically-released, carbon dioxide as evidence for life in a carbon dioxide atmosphere is an attendant problem. Solutions to these two problems were found and feasibility for the in situ approach was demonstrated. The techniques developed address themselves to the solution of the most difficult problem under Mars environmental conditions, that of maintaining a liquid water, moist environment for an in situ experiment. It must be stressed however, that lower levels of moisture requirements can be handled easily by these techniques.

A conceptual design of an in situ instrument and support equipment for the implementation of an in situ life detection system is included as part of this study.

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1.0 INTRODUCTION

In March, 1969, Biospherics Incorporated, then Biospherics Research Incorporated, initiated work on the "Study of the Feasibility of Conducting In Situ Life Detection" on Mars landed missions in connection with the 1973 unmanned flights to Mars as part of the NASA Viking Project.

In situ experiments for life detection appear highly desirable as opposed to experiments where samples are removed from their environment for examination. This is because the removal of samples disrupts the relationship between any organisms present and their natural environment.

The following section summarizes the subject study program and points out some of the highlights which culminated in the demonstration of feasibility of conducting in situ life detection experiments on Mars and in the presentation of a conceptual design for an in situ life detection instrument and supporting system.

The remaining sections present results obtained in the biology and engineering efforts in the program.

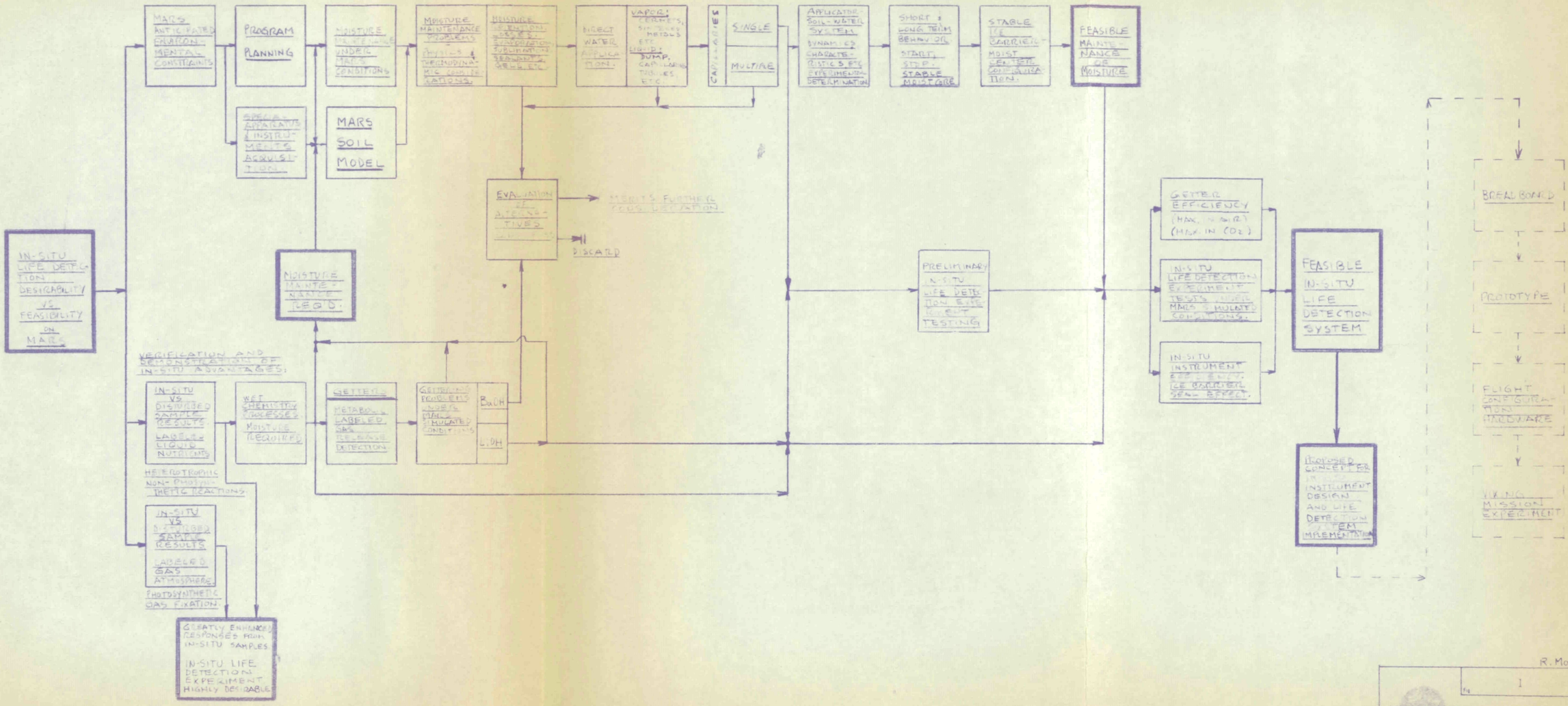
It is hoped that this contribution to the solution of conducting in situ experiments on Mars will lead to the next essential required steps toward implementation - that is to say, breadboarding, prototype, flight hardware configuration, and inclusion of the experiment as part of the Viking mission.

2.0 SUMMARY AND CONCLUSIONS

A systems program summary of the "Study of Feasibility of Conducting Mars Life Detection Experiment In Situ" is presented in a block diagram in Figure 1. A careful study of this systems chart will provide the reader with an excellent understanding of the structure of the study program. The program summary chart will also give the reader perspective concerning sections in this report dealing with specifics in the biology and engineering parts of the study, and how these fit into the overall picture.

The program itself has been divided essentially into five main, logical subdivisions: 1) statement of the problem; 2) preliminary work-acquisition of theoretical and experimental background, as well as acquisition of special equipment and materials, 3) experimental and theoretical study program with direct experimentation under simulated Martian conditions, 4) consolidation of the results and experience obtained in the study into the determination of feasibility, and 5) recommendations for future effort toward implementation of in situ life detection experiments on Mars.

The statement of the problem in its simplest form is the determination of whether an in situ experiment is indeed desirable, how desirable is it, and if desirable, is it possible to devise a practical scheme that will allow an in situ life detection experiment to be car-



SYSTEMS PROGRAM SUMMARY.
STUDY OF FEASIBILITY OF CONDUCTING MARS LIFE DETECTION EXPERIMENT IN-SITU.

R. MORENO

Fig. 1

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ried out under anticipated Martian environmental conditions and within the constraints of the mission. The answer furnished by this study is in the affirmative.

Biology experiments have been conducted and have established beyond a doubt that in situ life detection greatly enhances responses from in situ samples. Therefore, it is a highly desirable approach as compared to disturbed sample methods.

Early in the program, it was established that an important feature of an in situ life detection experiment is the provision and maintenance of water in vapor and liquid form because of this possible limiting factor on Mars. Later, it was established that in addition to the biological reason, water was required to promote the gettering of $^{14}CO_2$ by chemical methods as used in some of the candidate life detection experiments.

The solution to the problem of maintaining moisture under anticipated Martian conditions became the key to the feasibility of an in situ experiment. The bulk of the study effort centered about this problem. Several approaches were considered and tested, and the behavior of liquid and water vapor studied under simulated Martian conditions.

The eventual achievement of the development of a technique for the creation of an ice barrier to isolate and seal an experimental

volume, while maintaining a moist soil center within the volume, opened up the doors for testing of the heterotrophic life detection experiment under simulated Martian conditions. Results which indicate positive feasibility for the experiment were obtained. During this stage in the study, experiments were conducted to determine the influence of the ice-barrier seal effectiveness on the percent detector efficiency of the labeled carbon dioxide. Experiments were also performed to determine maximum getter efficiency in both air and carbon dioxide atmospheres to be used as reference points for getter efficiency. Labeled gas generators producing known amounts of radioactive carbon dioxide were used to remove the uncertainty of the biological labeled gas source. The results have led to the conclusion that an in situ life detection experiment can be carried out under anticipated Martian conditions and that metabolically-released labeled carbon dioxide can be effectively gettered in a $^{12}CO_2$ atmosphere by means of the in situ experimental mode developed in the course of this feasibility study.

3.0 BIOLOGY PROGRAM

3.1 Biological Investigation

3.1-A Study Objectives

The overall objectives of the Biology Program were to investigate, verify, and demonstrate the advantages of in situ life

detection experiments over sample removal experiments under terrestrial conditions, and to perform in situ experiments under simulated Martian conditions to determine in situ life detection effectiveness.

1. In Situ Advantages

The Viking Direct Biology Instrument Team stated that the advantages of an in situ life detection experiment were so great that the method should be developed even if it could not be implemented in time for a 1973 mission. The principal advantages given were: 1) minimum disturbance to the microecology; 2) less possibility of damaging the indigenous microorganisms; 3) photosynthetic organisms left in functional positions with respect to the light source; 4) expected experimental responses higher than those from disturbed samples; and 5) possibly most important, the obviation of the problem of removing the sample for life detection experiments. In addition, for those experiments in which liquid media were used, its application to the soil surfaces would permit the media to percolate to depths possibly not included in mechanically-removed samples. This experimental mode would also permit the ingredients of the media to provide a variety of concentrations because of the chromatographic effects of the soil. Similarly, the sample area would be provided with a variety of moisture levels. There was a strong feeling on the part of the Direct Biology Instrument Team that the ideal experiment

would be an in situ experiment conducted such that no changes were imposed on the ambient environment or on the constituents of the atmosphere and soil. It was acknowledged, however, that this ideal approach would be very difficult to develop into a practical experiment.

2. In Situ Available Schemes

The systematic evaluation of experiments suitable for life detection on Mars in an in situ configuration has established a limited number of schemes that are applicable within the constraints of state-of-the-art engineering technology and the present knowledge about the Martian environment. Among the various analytical tools presently available for instrumenting such experiments, radioisotope detecting devices permit the development of compact instrumentation for utilization in a small, extravehicular package configuration. The Gulliver radioisotope probe (labeled release experiment) and the autotrophic carbon dioxide fixation and release experiment have been examined within the constraints of current technology and form the substance of the biological program described in this report.

3. Labeled Release

The Gulliver instrument was originally conceived to conduct a "wet" experiment in which a sample of unknown soil was immersed in an aqueous medium containing a variety of labeled organic substrates. Because of the determination of low moisture content in the Martian atmosphere, the experiment was

modified to minimize the amount of water requirements and hence the amount imposed on the organisms so that the sample is merely moistened with the medium. Experiments were performed to measure the effectiveness of this "moist" assay under strictly terrestrial in situ conditions. In the laboratory, differences in response between intact soil surfaces and soil samples that were disrupted by sampling and encapsulation were compared under terrestrial and simulated Martian conditions. The data clearly indicated that the modified in situ labeled release experiment is highly suitable for deployment on the surface of Mars.

4. Biological vs. Physical Signal

An extensive investigation has been made on the detection of $^{14}CO_2$ incorporation photosynthetically and heterotrophically under both the encapsulated and in situ conditions. Methods have been evaluated for providing an in situ surface sample with a labeled CO_2 enriched atmosphere and, following a suitable light-incubation time, measuring the rate of re-evolution of labeled CO_2 from the organisms in the dark. Complications resulting from physical adsorption of $^{14}CO_2$ on soil particles with subsequent release posed a serious interference problem. This problem has now been resolved for the most part by use of exchange and gas flushing procedures prior to the measurement of the metabolically-released carbon dioxide. A compilation of the biological data gathered for each life detection experiment during the course of this program is presented.

3.2 Labeled Release Experiment

3.2-A In Situ vs. Disturbed Soil Responses

1. Experimental Set-Up and Procedure

The most advanced candidate experiment for

the in situ approach is the labeled release experiment. In this assay, an amount of labeled organic substrate is applied directly to the soil surface, and the level of microbial respiration of the test area is monitored by collecting the $^{14}CO_2$ evolved. The results of a typical in situ experiment are shown in Figure 2. Triplicate in situ experimental sites (A_1, A_2, and A_3) were selected on a laboratory-maintained soil plot. To each site was added 0.5 ml of RM-9 medium containing the four ^{14}C labeled compounds (glucose, glycine, lactate, and formate; 10 microcurie/ml total act.). Each site was covered with an inverted planchet for a one-minute incubation period, after which a barium hydroxide-wetted pad (getter pad) in an inverted planchet was placed over each site, and the evolved labeled carbon dioxide collected for one minute. The getter pad was then removed, and an empty planchet again was used to cover each site. At 5 and 60 minutes, the one-minute collection was repeated. All the barium hydroxide pads were dried and counted in a gas flow beta detector. Control sites (B_1, B_2, and B_3) were treated with 0.5 ml of concentrated Bard-Parker germicide, 15 minutes prior to the addition of the labeled-nutrient medium.

2. In Situ Response vs. Disturbed Soil Response

In order to test the concept that an in situ soil site will respond more rapidly and vigorously than one which has been disturbed, the following experiment was designed. Large slabs of topsoil were transferred, intact, to soil boxes in the

Sample	1 Minute Incubation (cpm)*	5 Minute Incubation (cpm)*	60 Minutes Incubation (cpm)*
A_1	79,447.0	86,525.0	57,074.0
A_2	59,073.0	128,927.0	29,293.0
A_3	31,868.0	105,226.0	31,950.0
Σx	170,388.0	320,678.0	118,317.0
$\bar{x}$	56,796.0	106,892.3	39,439.0
B_1	5,705.0	5,102.0	11,958.0
B_2	9,451.0	3,002.0	10,291.0
B_3	9,216.0	6,141.0	5,326.0
Σx	24,372.0	14,245.0	27,575.0
$\bar{x}$	8,124.0	4,738.3	9,191.6

The Evolution of $^{14}CO_2$ from In Situ Soil Samples

Assay: A - Soil + 0.5 ml RM-9 media (basal + ^{14}C substrates)

B - Soil + 0.5 ml RM-9 media (basal + ^{14}C substrates) + 0.5 ml Bard-Parker germicide

* All values corrected for background of 26 cpm. Samples collected for 1 minute.

Fig 2

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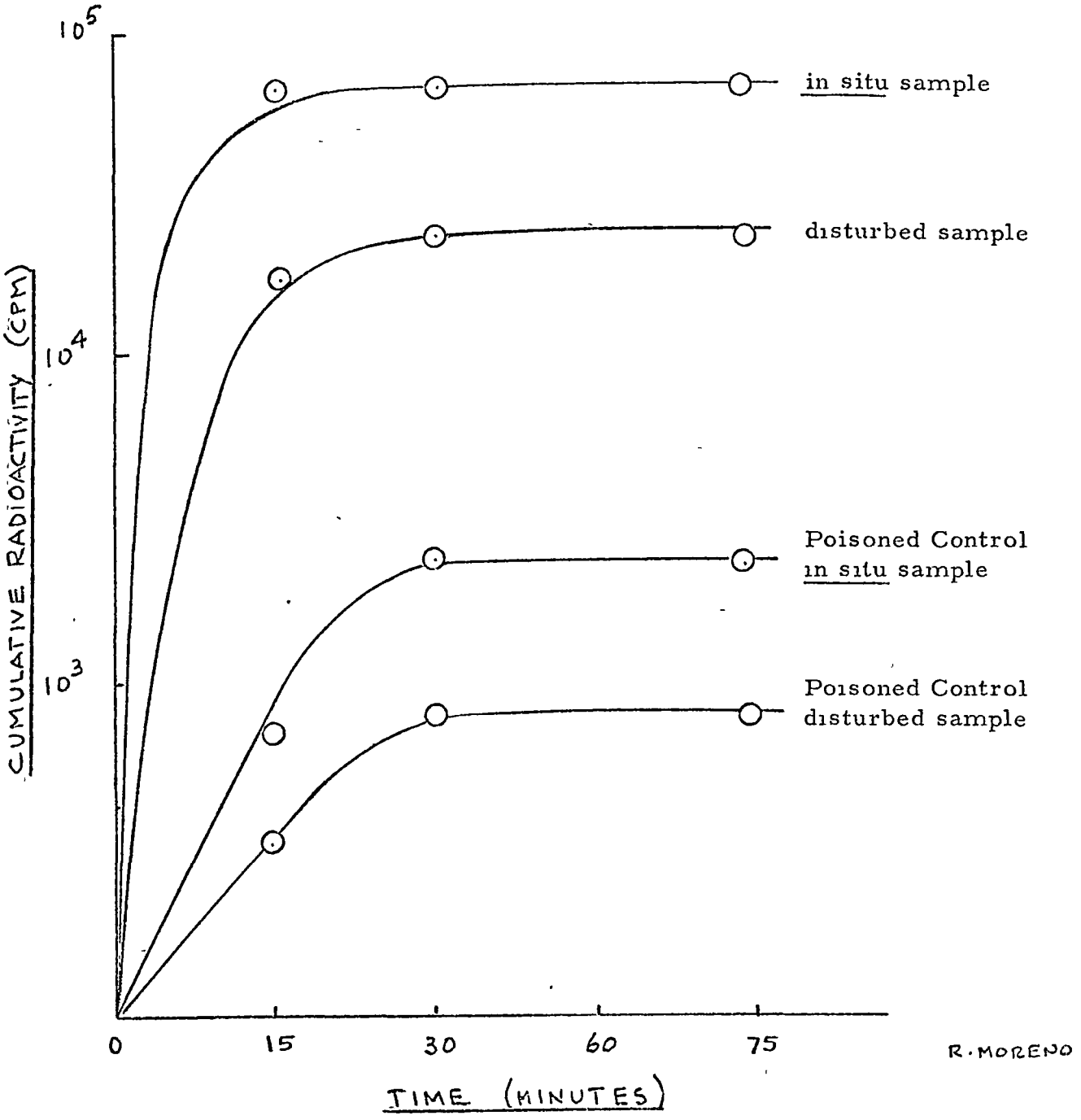
laboratory where they were maintained under ambient conditions for one week. Daily watering was applied. Portions of the soil were dug to a depth of about 2 cm, mixed in place, and recompacted to the original soil profile. These sites served as the disturbed and control samples. One-ml (1.0 ml) portions of Bard-Parker germicide were applied to the control portions. Thirty minutes later, 0.2 ml of RM-9 + ^{14}C medium (2.6 microcuries) was applied to each test and control site. A planchet containing a barium hydroxide getter pad was positioned over each experimental site and was replaced five times, once every 15 minutes for 75 minutes.

The results of this experiment are presented in Figure 3. Each point shown is an average of triplicate determinations. It is seen that the average responses from the in situ sites were more rapid and of greater intensities than from the disturbed soil sites. After only 15 minutes, the in situ response approached 10^5 cpm while the disturbed response was lower by about a factor of four. These data tend to agree with the philosophy of the in situ concept. However, to conclude a priori whether this expected response is universal for soils would have required an extensive test program on a geographically diverse spectrum of soil samples of many different physical-chemical compositions.

3.2-B Effect of Sample Size and Moisture Content

An important tenet of the in situ concept is that



Comparison of In Situ Gulliver on Intact and Disturbed Soils

Assay Conditions

Sample - Soil in situ vs. disturbed
Medium - RM-9 + 4 ^{14}C Organics - 0.2 ml
Isotope - 2.6 µCi
Incubation - 75 minutes, 28°C
Poison - 1.0 ml Bard-Parker, 30 min. pre-inoculation

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 3		
	12-69 Date	Init	Scale
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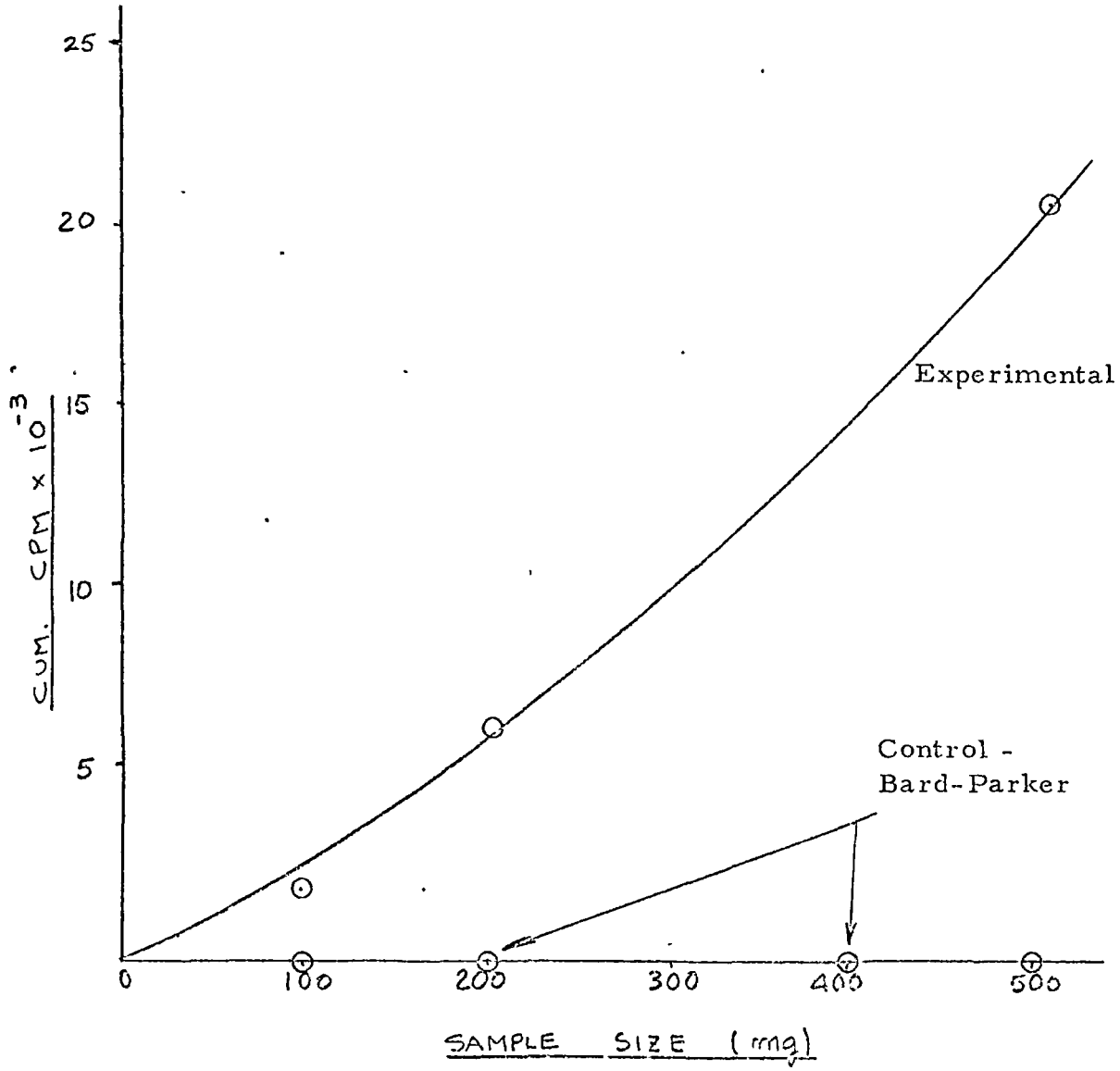
a larger soil sample will be available for assay than in an encapsulated experiment. This would be so because the liquid nutrient could freely penetrate the essentially unlimited sample in three dimensions, but depending upon such soil conditions as porosity and moisture content.

1. Experimental Data

As shown in Figure 4, the biological signals were directly proportional to soil sample size, up to at least 500 milligrams when a fixed volume of labeled medium (0.2 ml, 2.6 uCi) was supplied. In Figure 5 are shown the results of a similar experiment in which a more arid soil sample, in increasing amounts, was tested with a fixed amount of labeled medium (0.4 ml, 4 uCi). A proportional signal was obtained only with a soil size up to 200 mg, above which the signals deviated from linearity. Either the amount of soil available to a fixed volume of medium was limited by permeability of the soil, or approximately 200 mg of soil utilized the total supply of the medium.

2. Enhancement of Metabolic Activity of Dry Soils by the Addition of Water

In the labeled release experiment, supplemental water was demonstrated to significantly enhance the metabolic activity of some soils. When supplemental moisture (0.2 ml) was applied to two test soils prior to assay, a significant enhancement in the evolution of $^{14}CO_2$ was observed in both cases. Figure 6 shows the results obtained



Effect of Sample Size of
Labeled Carbon Dioxide Evolved from Soil

Assay Conditions.
Sample - Top Soil
Medium - RM-9 + 4 ^{14}C Organics
Getter - $Ba(OH)_2$ Pad
Collection Period - 2 hrs.
Isotope - 2.6 μCi/0.2 ml (medium)

	Fig. 4		
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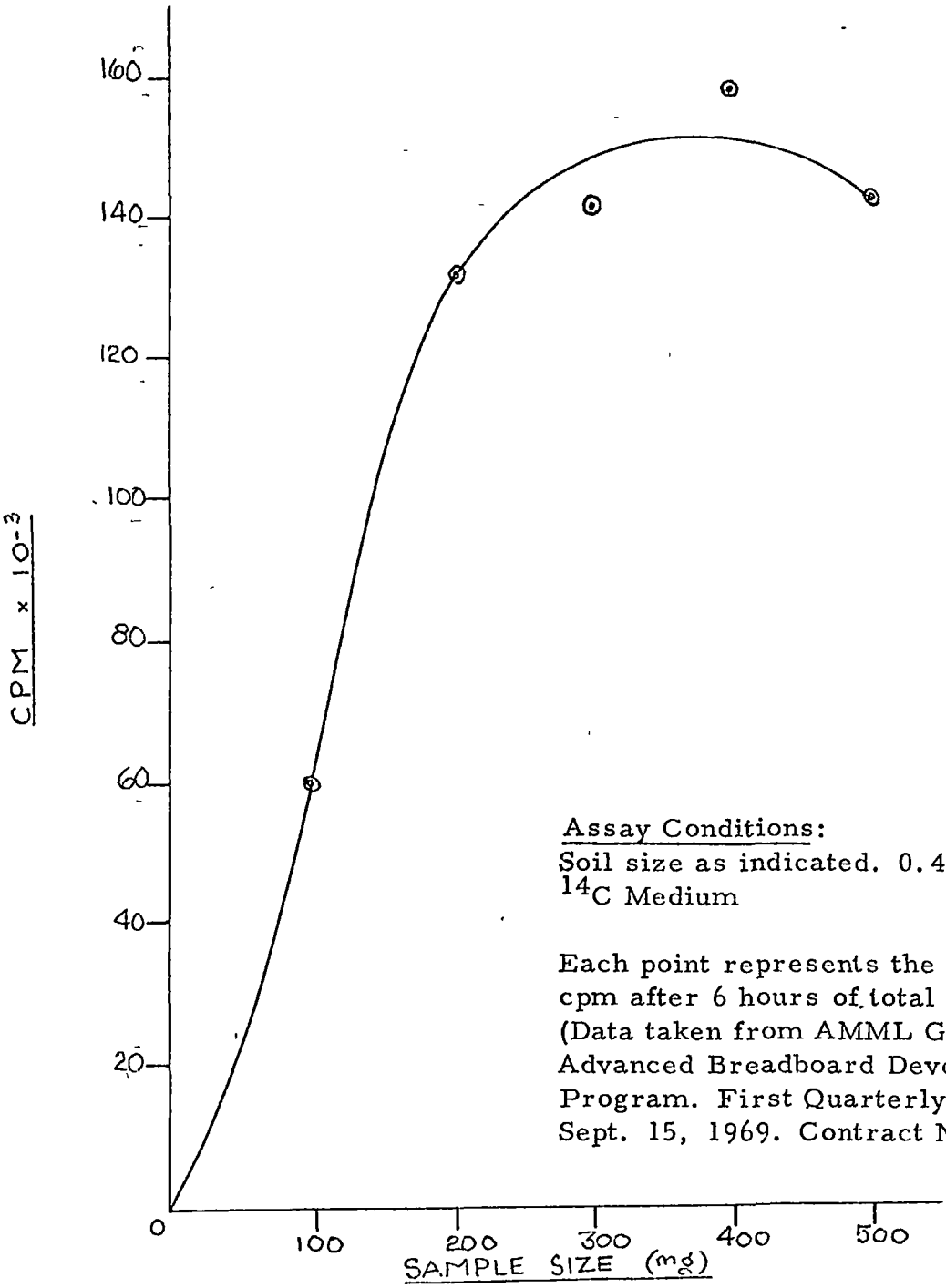

Assay Conditions:
Soil size as indicated. 0.4 ml M9 + ^{14}C Medium

Each point represents the cumulative cpm after 6 hours of total gettering. (Data taken from AMML Gulliver V Advanced Breadboard Development Program. First Quarterly Report, Sept. 15, 1969. Contract No. NASW-1931)

Effect of Soil Sample Size on the Labeled Release Response

BIOCS INCORPORATED Rockville Maryland	Fig 5	
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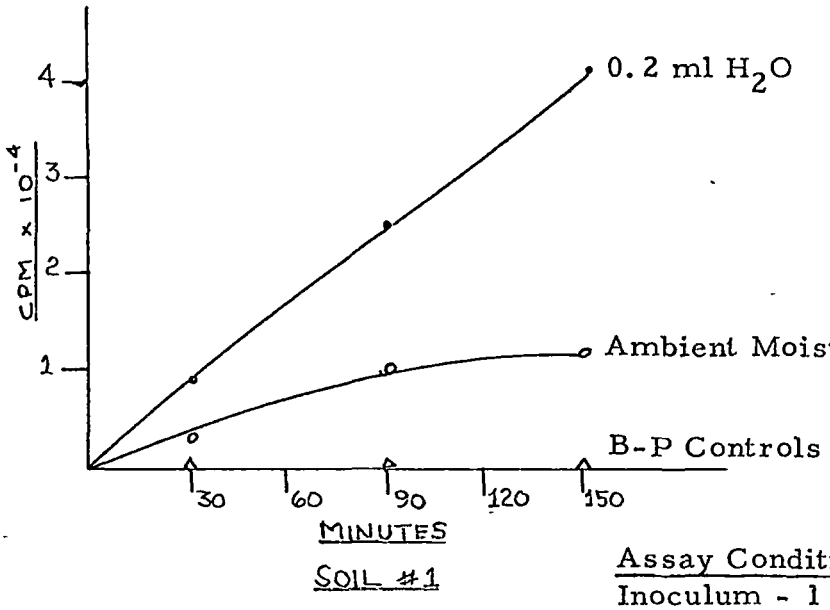
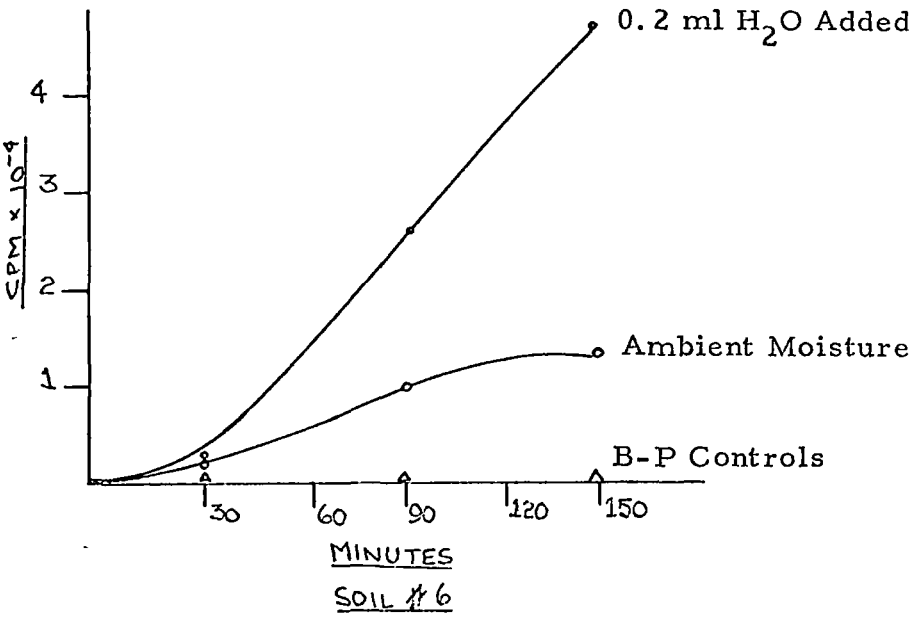
NAS2-5360 Cont. No.	In Situ Life Detection on Mars Report Title	



Assay Conditions:
Inoculum - 1 gm Test Soil
Isotope - 2.0 uCi ^{14}C Organics +
0.2 ml RM-9
Ambient Moisture - #1 - 0.26%
#6 - 3.60%



Effect of Supplemental Moisture on $^{14}CO_2$ Evolution from ARC Test Soils

BIONICS INCOPPORATED Rockville Maryland	Fig 6		
	12-69 Date	Init	Scale
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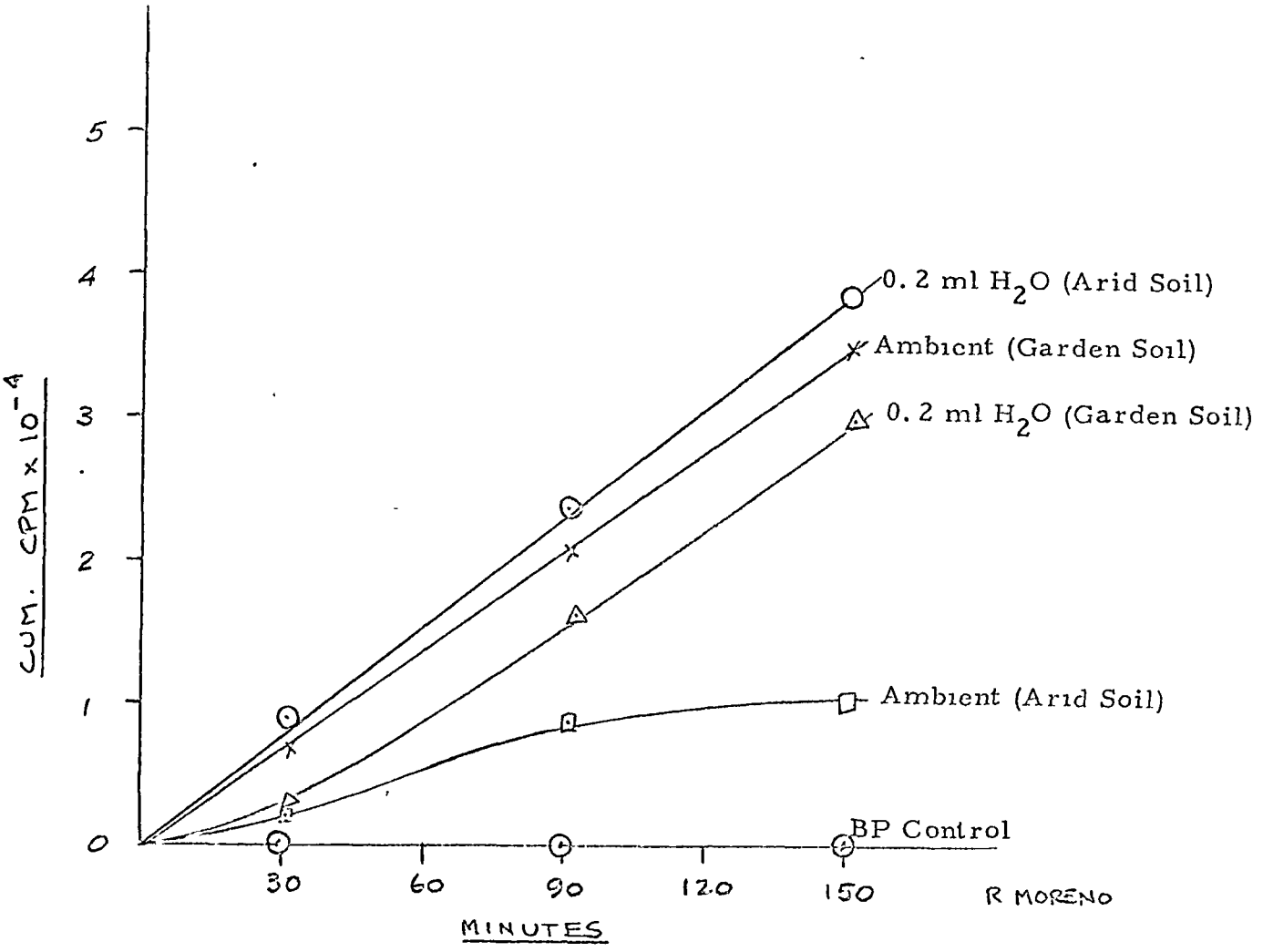
with ARC samples No. 1 and 6. The determined ambient moisture contents were considerably different in the two soils (No. 1 - 0.26%; No. 6 - 3.6%), yet the elevated responses were about equivalent upon the addition of water. The data presented in Figure 7 demonstrates that added water to the soil sample in the labeled release experiment usually shows a dramatic difference was observed with soils having relatively high natural levels of ambient moisture (about 5%). This data would support the inclusion of a method for supplementing the test samples with at least small quantities of liquid water.

3.2-C Labeled Release Experiment Under In Situ Simulated Martian Conditions

The initial attempts of the labeled release experiment performed in a simulated in situ soil plot, using the capillary applicator technique under simulated Martian conditions were beset with mechanical problems.

1. Effect of Simulated Martian Conditions on Terrestrial Organisms

Soil plots heavily seeded with a soil-isolated psychrophile when exposed to the Martian environment failed to respond to the labeled release test. In general, the amount of labeled CO_2 collected over the experimental soils was not significantly different from that collected over Bard-Parker treated soils over a



Effect of Supplemental Moisture on $^{14}CO_2$ Evolution from Heterotrophic Release Test

Assay Conditions·
Isotope - 1.3 uCi ^{14}C organics
Soil - 200 mg garden/arid
Moisture Content - 0.2 ml
Control - Ambient moisture

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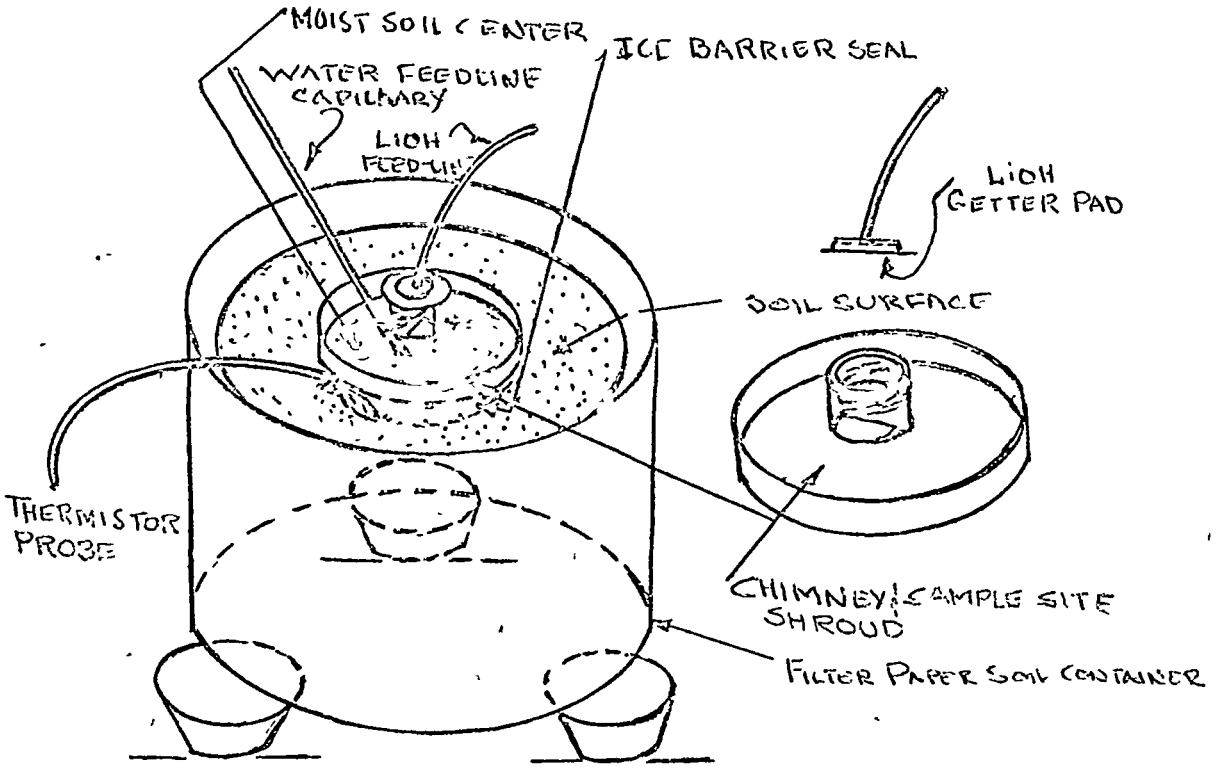
four-hour continuous run in the environmental chamber.

Subsequent to these preliminary experiments, and with a better understanding of the kinetics of ice-barrier formation, biological activity was demonstrated with the psychrophiles in the simulated in situ soil plots. Most of the mechanical problems were resolved by control of the soil temperature in the range of 10° C to 14° C while the chamber wall temperature was maintained at 8° C to 10° C. These temperatures were determined as a part of the engineering effort in establishing parameters for the stable ice barrier-moist core configuration under simulated Martian conditions. They were maintained during a water supply rate of 5 ml-per-hour. Figure 8 shows the arrangement of the experimental apparatus employed in these experiments.

2. Responses of Terrestrial Organisms Under Isolated Experimental Volume (Ice Barrier)

The high vacuum and low moisture of Mars simulation undoubtedly results in cellular desiccation soon after the seeded soils are exposed. A significant number of cells succumb as a result of this stress. To minimize this effect, suspensions of the psychrophiles (10^9 to 10^{10} cells/ml) were injected into the soil in the Mars simulator directly via the capillary applicators, following pre-formation of the ice barrier-moist core complex.



B. FORSTEL 12/

In Situ Apparatus for Labeled Release Experiment
Conducted under Simulated Martian Conditions

	Fig 8			
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Rockville Maryland	Date 12-69	Init	Scale	
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After initiating the ice barrier with an injection of 2.5 ml of ice water (at approximately 4° C), 2.5 ml of the psychrophilic cell suspension (about 3 x 10^{10} cells/ml) in basal M9 medium was injected into the experimental volume through the capillary applicator. Prior to injection into the soil, control cells were treated with Bard-Parker germicide at 4° C for sixty to ninety minutes. Next, 1.0 ml of labeled M9 medium (10 microcurie/ml) was injected via the applicator to each of the two soils. The feedlines to each getter pad were filled with 0.4 ml of saturated lithium hydroxide to initially wet the pads. At regular intervals thereafter, the getter pads were rewetted with 0.2 ml volumes of a 10X diluted solution of the saturated lithium hydroxide. Injections of labeled medium were made at various times to replenish nutrients to the in situ test areas.

As shown in Figure 9, the signals obtained from the test soils exceeded those of the parallel controls in all cases. With the labeled M9 medium, the ratios of test-to-control signals ranged from 1.7/1.0 to 28/1.0 with a mean response of 11.2/1.0 after three to four hours of continuous gettering.

3. Effect of Depth of Injection on Response

When the applicator depth was increased, the indication was that the biological response decreases with increasing depth from the in situ surface.

Date of Experiment	Total Gettering Time (hrs)	Capillary Applicator Depth (cm)	Labeled Medium (10 uCi/ml)	CPM	
				Test	Control
9/30/69	4	#	M-9	1220	708
10/1/69	3 3/4	#	M-9	1643	58
10/13/69	4	#	M-9	645	124
10/14/69	4	#	M-9	853	57
10/24/69	4	surface	M-9	146	37
10/15/69	5	surface	M-11	4550	467
10/16/69	4	1	M-11	488	15
10/20/69	4 3/4	2	M-11	238	45
10/22/69	3 1/4	surface	M-11	2079	358

Total CPM of $^{14}CO_2$ Collected from Psychrophilic Bacteria Treated and Non-treated with Bard-Parker Germicide by the In Situ Labeled Release Test under Simulated Martian Conditions.

Not measured but between 1 cm and 3 cm below surface.

4. Effect of Degree of Seal Effectiveness Between Ice Barrier and Experiment Volume Shroud

Attempts were made to further improve the level of the biological signal under simulated Martian conditions. This was achieved by establishing an ice barrier to effect a complete seal of the experiment volume. In this manner, evolved labeled carbon dioxide was more effectively contained within the controlled volume where it was considered more available for gettering.

To accomplish the ice-barrier seal, a glass cylinder (16 mm x 35 mm) in place of the petri plate-baffle apparatus (Figure 8) was set on the soil surface to a depth of 0.5 cm to 1.0 cm. The capillary applicator, which supplies a continuous flow of water, was set in the center of the soil area enclosed by the glass cylinder and about 0.5 cm to 0.75 cm below the soil surface. In this way, the moist core-ice barrier grows symmetrically in the horizontal and vertical planes from the controlled volume center. Initially, about 4 ml of ice water (4° C) was injected into the soil via the applicator to establish conditions for ice-barrier formation. Soil temperature, wall temperature, and continuous flow were as before.

After about one hour of ice-barrier formation, 2.5 ml of psychrophilic bacteria (5×10^9 cells/ml) were slowly injected into the soil via the capillary applicator. Immediately, 1 ml of labeled M9 medium (10 microcurie/ml) was injected. The getter pad was wetted with lithium

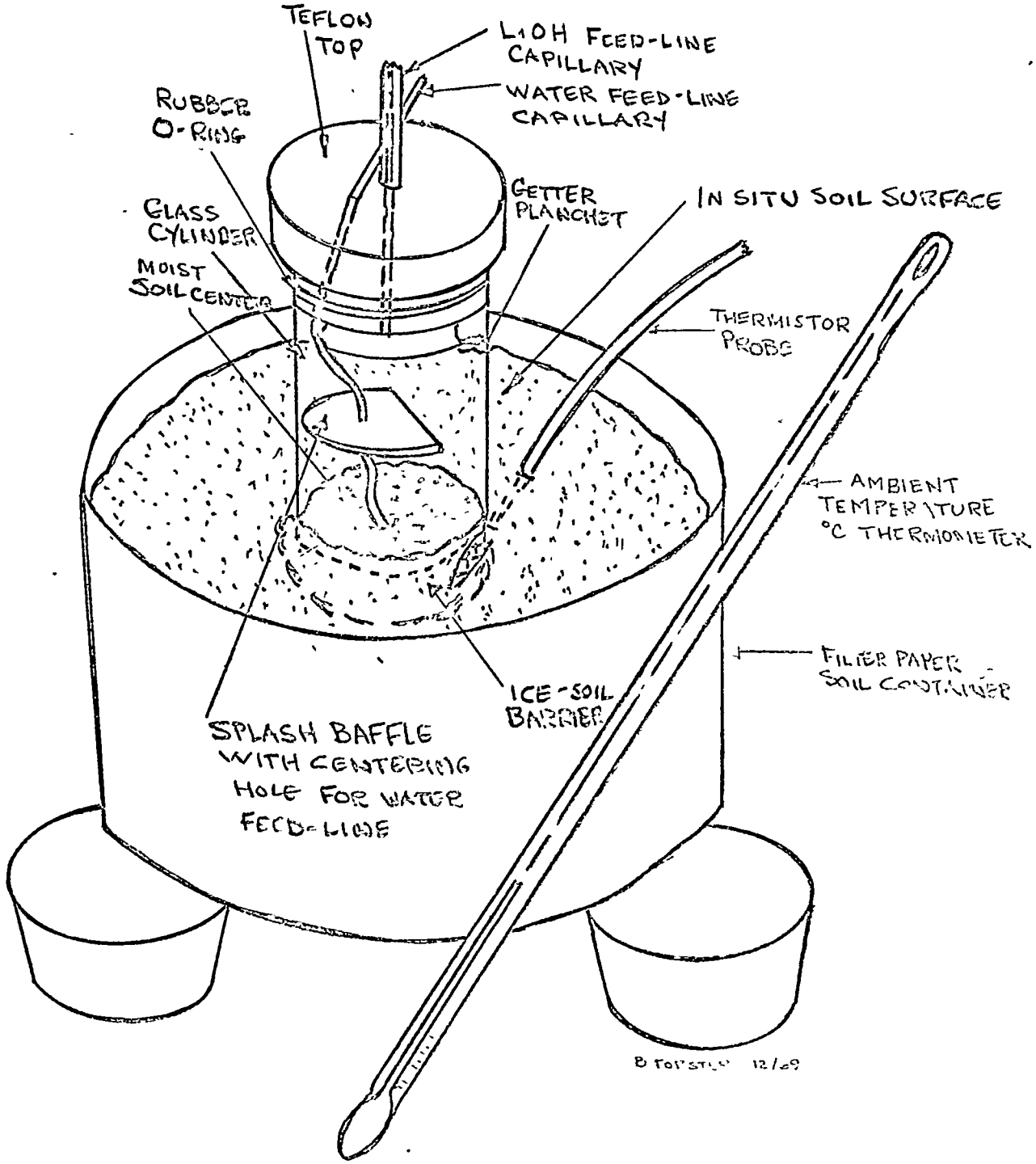
hydroxide and then intermittently re-wetted with it approximately every half-hour. The experimental run was usually for four continuous hours under simulated Martian conditions, and nutrients were re-applied at various intervals. Figure 10 shows the arrangement of the apparatus. Figure 11 shows the results of four independent experiments employing the modified apparatus. It can be seen that the feasibility of detecting metabolically-evolved labeled carbon dioxide from the terrestrial test organisms under simulated Martian conditions with this modification was excellent. Responses were considerably higher than those shown in Figure 9. It now appears that the modified experimental volume results in an improved ice-barrier seal without altering the moist core. By constantly maintaining the moisture of the getter pad with getter solution, available gettering at the pad surface is ensured.

3.3 Light Fixation-Dark Release Experiment

3.3-A Disturbed vs. In Situ Photosynthetic Response

1. Effect of Disturbance of Sample on Photosynthetic Response

The in situ testing for metabolic activity of photosynthetic organisms obviates the re-distribution of phototrophic organisms in mechanically-retrieved soil samples taken for life detection tests. Since it may be reasonably assumed that the organisms having the most active photosynthetic activity would be



Modified Experiment Volume Apparatus

	Fig 10	
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NAS2-5300	In Situ Life Detection	

Experiment #1	CPM Collected	Frequency of Getter Pad Rewetting (LiOH)	Getter Pad Appearance at Termination of Experiment
Replicate 1	3,931	twice, 0.2 ml each	nearly dry
Replicate 2	8,438	twice, 0.2 ml each	moist

Experiment #2	CPM Collected	Frequency of Getter Pad Rewetting (LiOH)	Getter Pad Appearance at Termination of Experiment
Replicate 1	13,623	four times, 0.2 ml each	moist
Replicate 2	26,683	four times, 0.2 ml each	wet

Labeled Release Response In Situ
Modified Experiment Volume

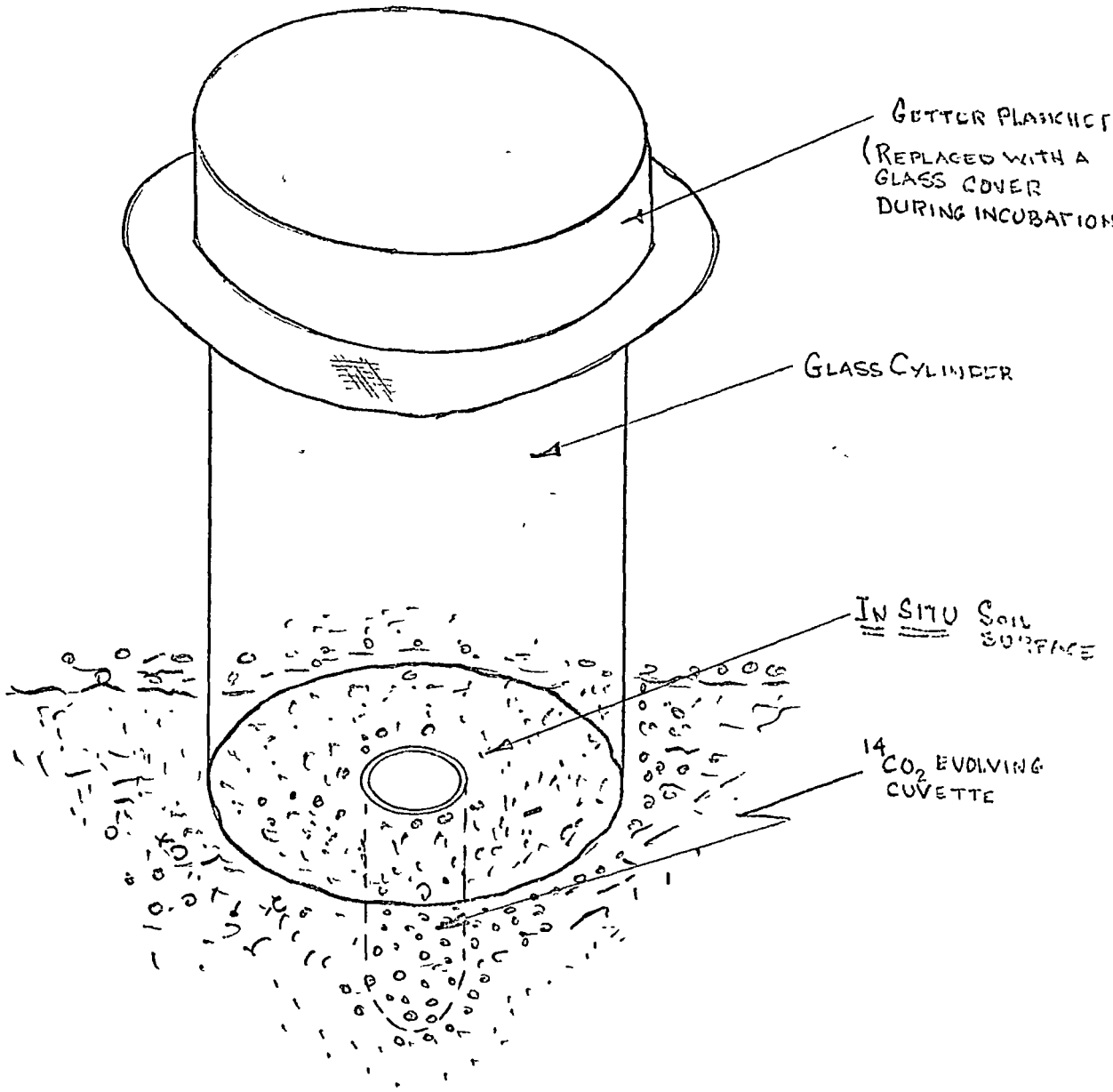
found primarily concentrated very close to the soil surface of Mars and oriented toward the available light, any disruption of the soil surface might be anticipated to decrease the response in the photosynthetic assay.

2. Laboratory Experiment In Situ

Laboratory investigations, similar to those discussed for the labeled release experiment, were made to test the premise that photosynthetic activity in soil will be diminished upon disturbing the soil surface. The experimental apparatus used in conducting these experiments is shown in Figure 12. In Figure 13 are shown the accumulated data from several experiments on soils obtained from different environments and maintained under laboratory conditions. Responses from soils in three experimental configurations clearly confirm the supposed advantages for in situ monitoring of photosynthetic organisms.

3. Field Experiment In Situ

Field testing of the photosynthetic and dark release experiment was made under natural in situ conditions. With a three-hour illumination period under natural sunlight, a surface sample from a well-kept lawn from which the grass had been carefully removed (to prevent grass response), was monitored for its ability to fix and release labeled carbon dioxide. Within three hours following termination of the light incubation, demonstration of respiratory activity was obtained from samples which had been exposed to the light. Comparison with a sample which had been disrupted prior to the test showed that within two hours, the in situ response was about twice that of the disrupted



IN SITU AUTOTROPHIC PHOTOSYNTHESIS APPARATUS

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BIOTICS INCORPORATED, Rockville Maryland	Fig 12		
	12-69 Date	Init	Scale
NAS2-5360	In Situ Life Detection on Mars		

Response (CPM)

Experiment Number	In Situ	Disturbed	Disturbed Recompacted	Optimum Configuration
1	1,987	411	1,248	In Situ
2	662	561	-	In Situ
3	649	847	-	Disturbed
4	440	2,546	581	Disturbed
5	1,156	170	-	In Situ
6	371	420	502	Disturbed Recompacted
7	1,679	185	-	In Situ
8	1,693	1,017	-	In Situ
9	960	791	-	In Situ
10	7,038	7,604	8,103	Disturbed Recompacted
11	31,386	7,249	23,102	In Situ
12	364	269	-	In Situ

Summary of Comparison Tests of Soil Configuration
for In Situ Feasibility Study
Photosynthetic $^{14}CO_2$ Evolution

Assay: Radioisotope - 1.0 uCi $NaH^{14}CO_3$
Incubation - 3 hours at 300-500 foot candles
Soil Type - Garden
Gas Collection Time - 3 hours
Gas Volume - 10 ml

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 13		
	12-69 Date	Init	Scale
NAS2-5360	In Situ Life Detection on Mars		

sample. Dark controls and soil samples pretreated with Bard-Parker germicide showed an attenuated response. The results of this experiment are shown in Figure 14. These data clearly demonstrated and confirmed the early laboratory tests which indicated that the detection of photosynthetic activity in soils is enhanced by the in situ method.

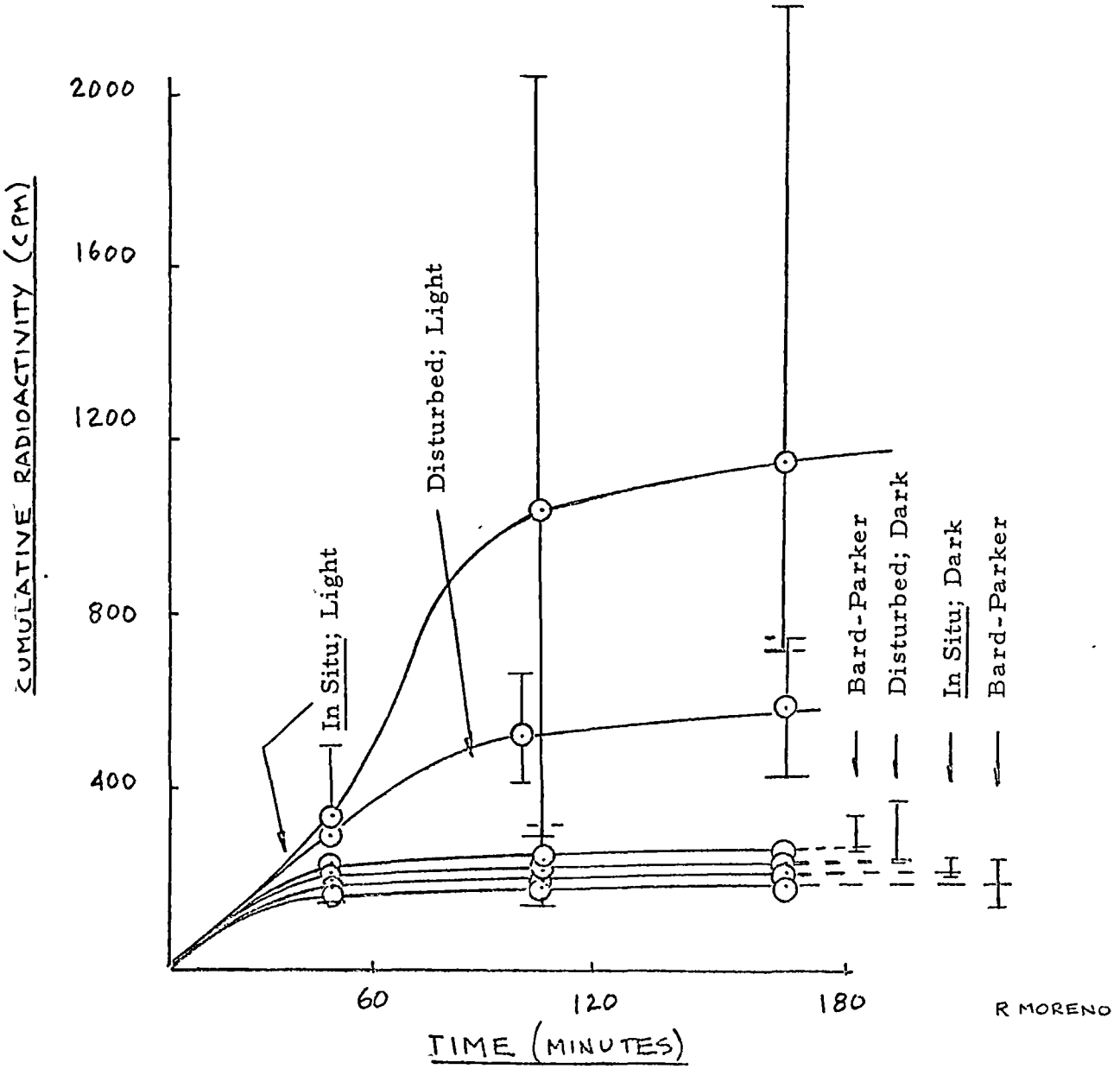
4. In Situ Responses from Soils with Added Phototrophs

Comparative results obtained by the photosynthetic assay from undisturbed soil samples containing moss or soil to which algal cells were added are presented in Figures 15 and 16, respectively. In each case , the undisturbed soil surface samples resulted in more accelerated responses than the samples which had been mechanically disturbed to simulate the action of mechanical sampling of soil. Figure 16 also demonstrates the decrease of photosynthetic activity with depth of soil. This further demonstrates the importance of the in situ approach to phototroph detection.

3.3-B Effects of Moisture Addition on the Photosynthetic Response

1. Enhancement

As in the case of the labeled release experiment, the addition of water to dry soils was shown to enhance the biological response in the photosynthetic test. Both isolated and in situ soil samples have been compared to photosynthetic responses in the presence of supplemented soil moisture. Figure 17 and 18 compare



Field Test #1 - Photosynthetic Fixation
and Dark Release Experiment

Assay Conditions

Soil - In Situ, 1246 Taylor Street, N. W., Washington, D. C.
Radioactivity - $^{14}CO_2$, 0.1 μCi/ml Gas Volume
Collection Period - 3 hours
Getter - Saturated LiOH Pad

BIOSCIENCES INCORPORATED Rockville Maryland	Fig 14		
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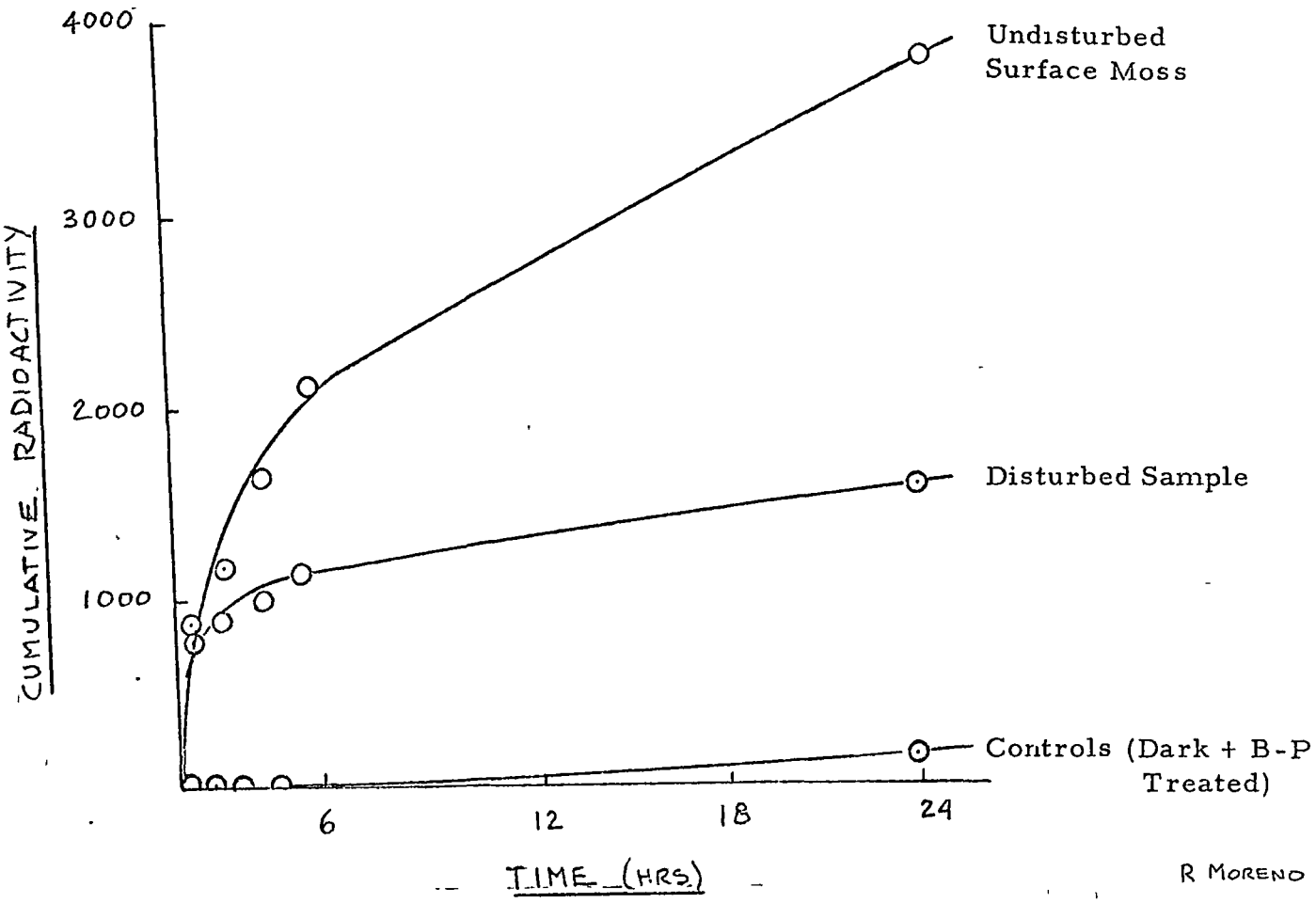


Evolution of $^{14}CO_2$ from Soil Samples Containing Moss

Assay Conditions

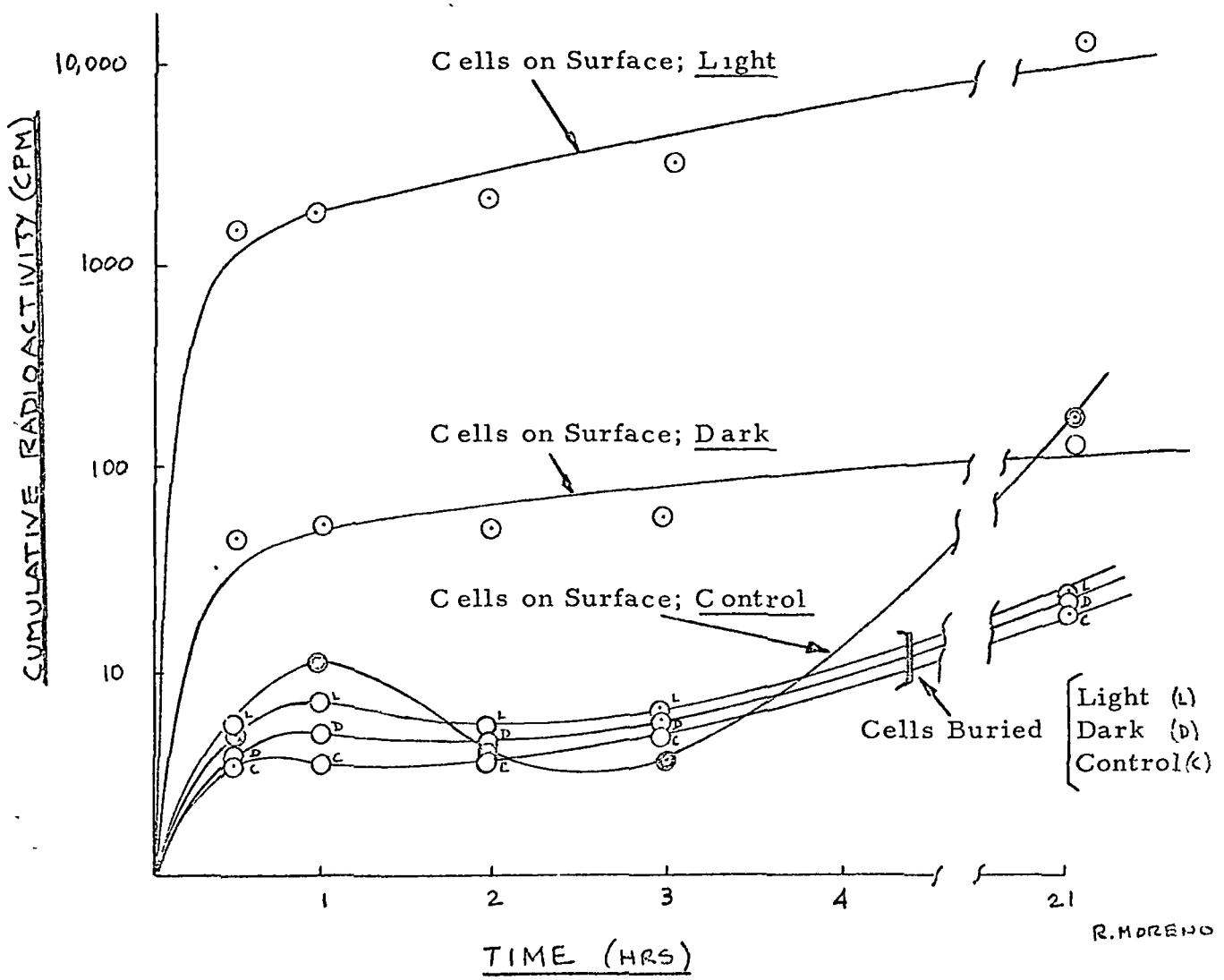
Isotope - luCi NaH $^{14}CO_3$/10 cc

Sample - Garden Soil with Moss Supplement

Illumination - 500 Foot Candles for Three Hours

Control - 1.0 ml Bard-Parker Germicide

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 15		
	12-69 Date	Init	Scale
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		



Photosynthetic Evolution of $^{14}CO_2$ from Algal Cells on Soil Surface Compared to Activity of Cells Distributed Uniformly Throughout 0.5 gm of Garden Soil Prior to Light Exposure.

ASSAY CONDITIONS·

Soil - 0.5 gm garden
Incubation - 3 hrs/500 foot candles
Isotope - 1.0 μC1 $NaH^{14}CO_3$
Control - 1.0 ml Bard-Parker
15 minutes prior to test
Water Supplement - 1.0 ml (sterile distilled)

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 16		
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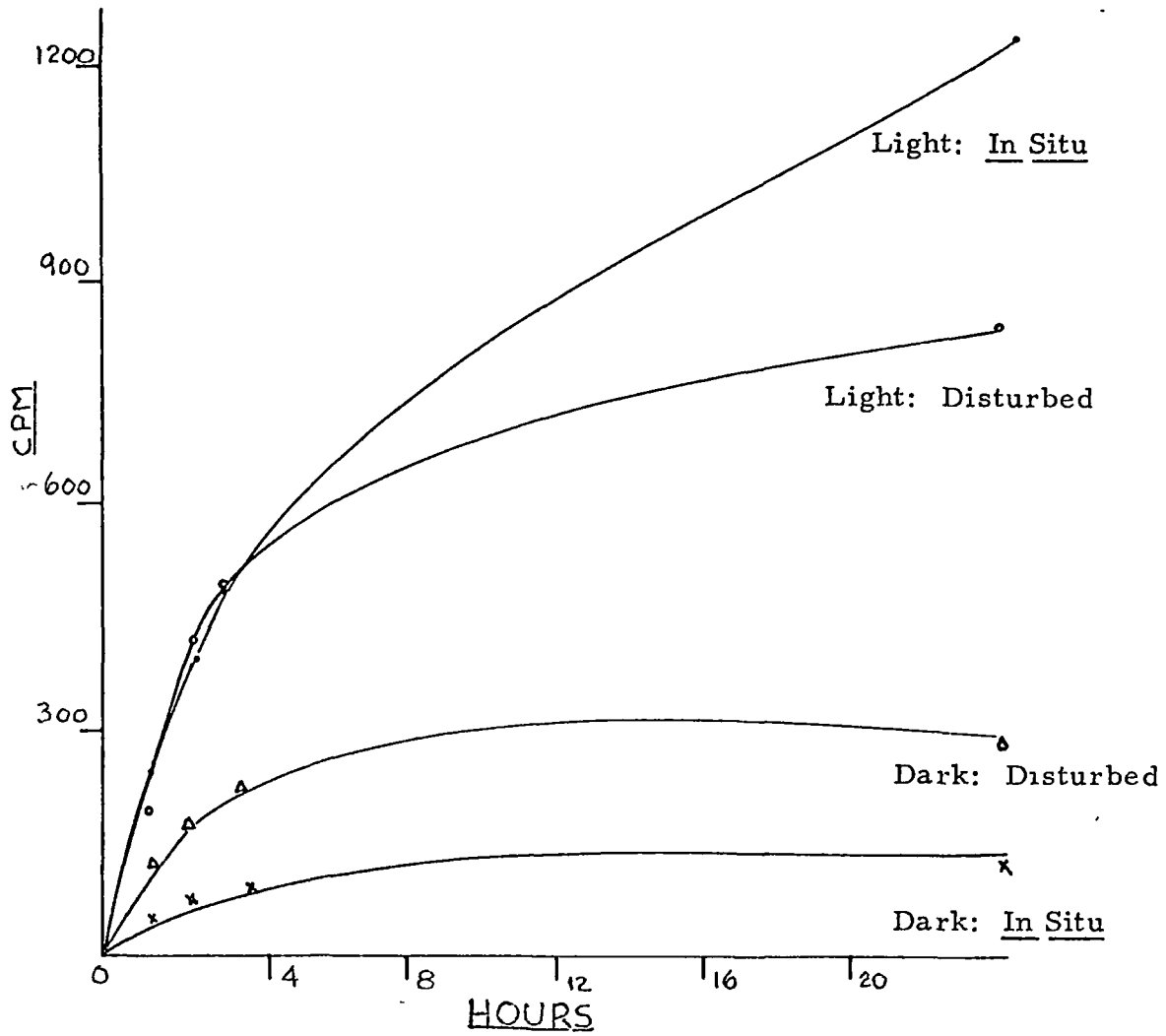
NAS2-5360	In Situ Life Detection		



Ambient Soil Moisture Effect on the Photosynthetic Assay on Intact and Disturbed Soils

Assay Conditions:
Sample - Soil Plot
Isotope - 1 uCi $NaH^{14}CO_3$
Incubation - 500 foot candles for 3 hrs.

BIOCS INCORPORATED Rockville Maryland	Fig 17		
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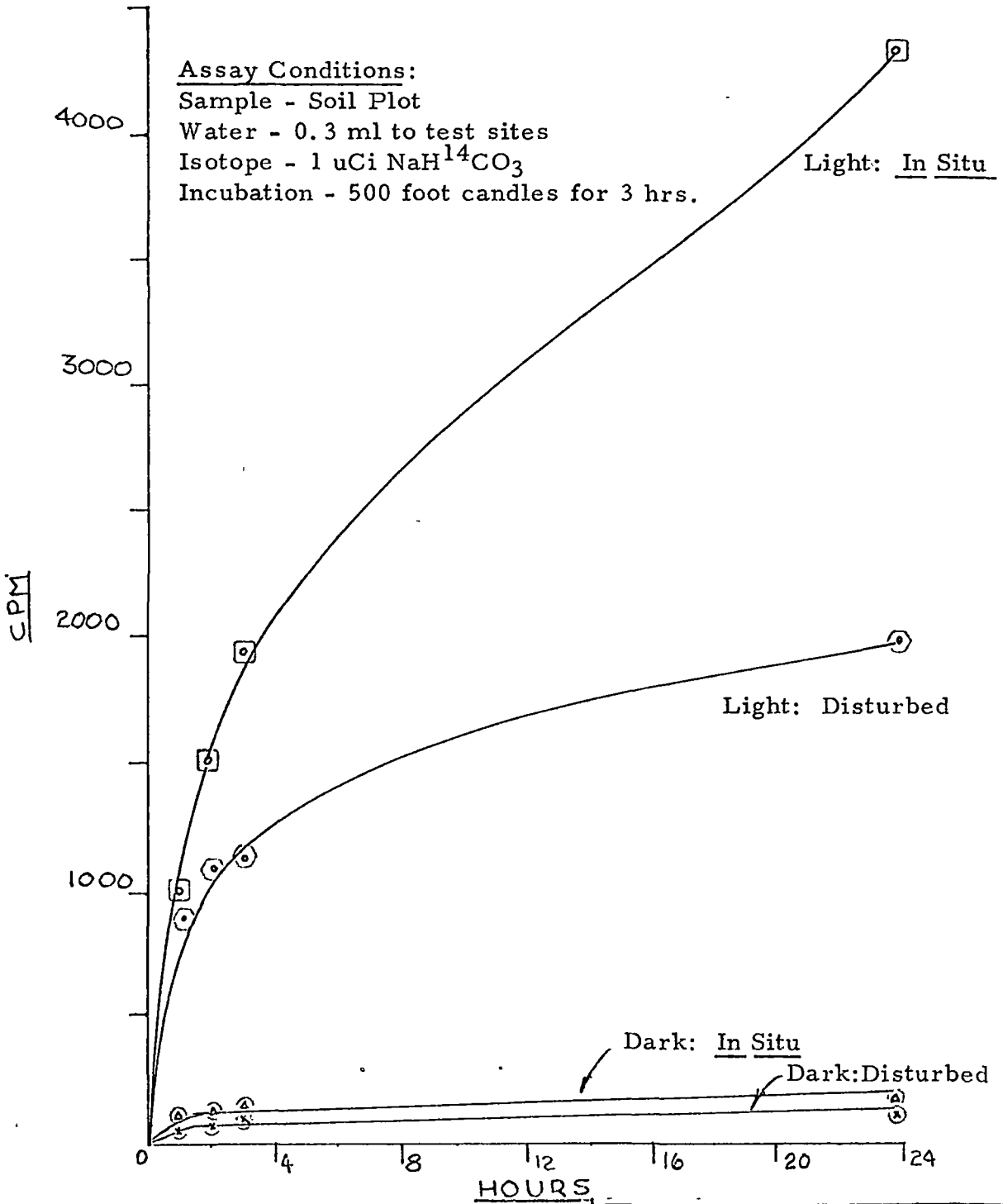
NAS2-5360	In Situ Life Detection on Mars		



Effect of Added Moisture on the Photosynthetic Assay on Intact and Disturbed Soils

Fig	18
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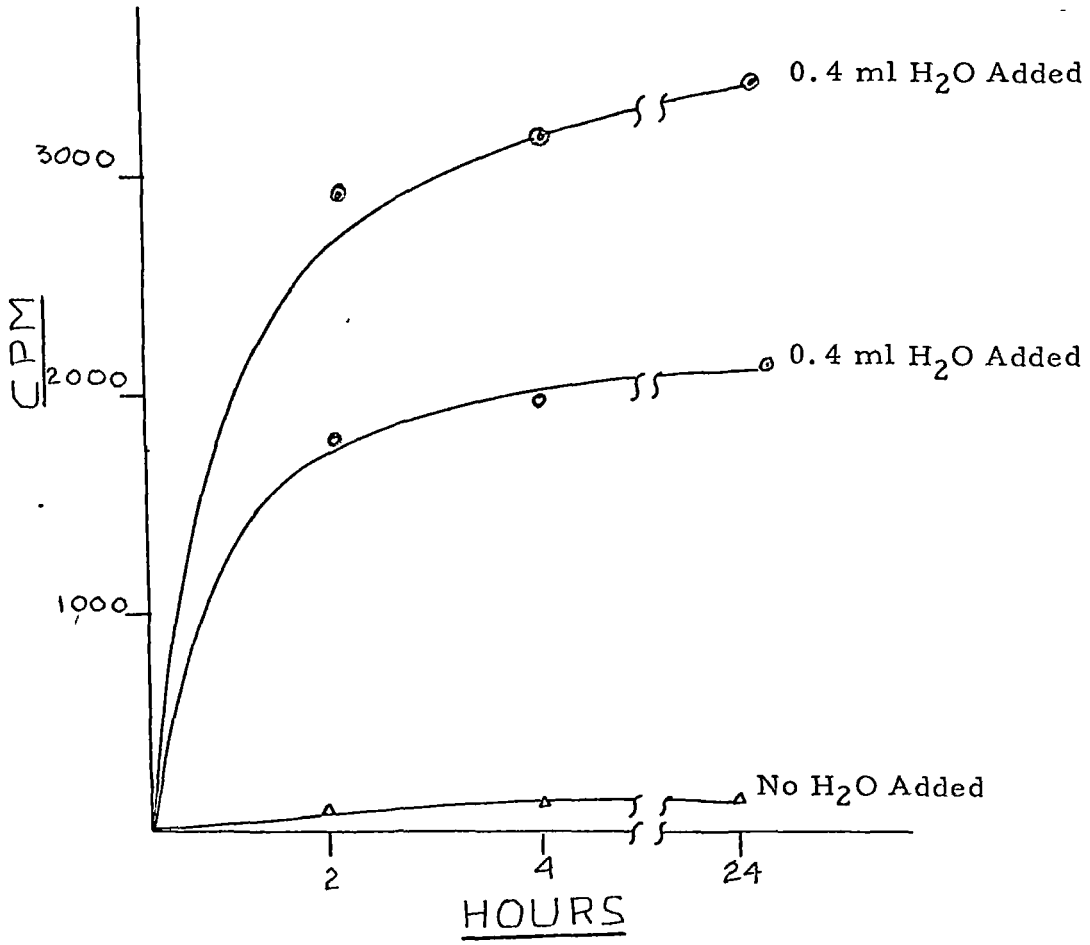
Date 12-69	Init. / Scale
NAS2-5360	In Situ Life Detection on Mars

the effect of added moisture (0.3 ml H_2O) and ambient moisture on the photosynthetic assay on both intact and disturbed soil sites. Upon the addition of moisture, the light intact site and the light disturbed site responded about four times and three times, respectively, higher than the corresponding sites at ambient moisture content. The dark, incubated, dark-release responses were not greatly different in the presence or absence of added moisture. A further demonstration of the elevated response on moisture addition is shown in Figure 19, with soil samples subjected to the photosynthesis assay in the encapsulated configuration. The evidence presented here indicates that the attribute of added moisture in stimulating the photosynthesis response is beneficial when applied to arid soils. Increasing moisture content appears to increase the concentration of dissolved $^{14}CO_2$, thus facilitating the ability of the carbon dioxide-fixing organisms to sequester the labeled gas.

2. Complication for Dark Release Experiment

A disadvantage of the addition of high moisture content is stimulation of a rapid release of nonbiologically-fixed $^{14}CO_2$ from the soil during the dark-release portion of the experiment. The complication produced by this undesirable effect has been investigated in an associated program. The effort made in resolving this problem led to the demonstration that a moist $^{12}CO_2$ flush for about one hour following incubation with $^{14}CO_2$ rapidly and



Effect of Supplemental Moisture on the $^{14}CO_2$ Fixation and Relcase Test from an Arid Soil

Assay Conditions:
Illumination - 500 foot candles for 3 hrs.
Isotope - 1 μCi $NaH^{14}CO_3$
Soil - 0.5 gm Air Dried Garden Soil
Gas Volume - 10 ml

	Fig 19			
BIONICS INCORPORATED Rockville Maryland	12-69 Date	Init	Scale	
NAS2-5360	In Situ Life Detection			

efficiently removed the nonbiologically-fixed $^{14}CO_2$. The most significant reductions in the levels of nonbiological response were shown to occur with soils to which moisture was added prior to light incubation, and flushing was with moisture-saturated $^{12}CO_2$. This system seems to offer a satisfactory solution.

3.3-C Light Fixation and Dark Release Test Under Simulated Martian Conditions

The performance of the photosynthetic assay under simulated Martian conditions has not been examined as extensively as the labeled release test. The requirement for an elaborate apparatus in which the various phases and manipulations of the assay are carried out entirely within the Martian environment has limited such investigations.

Some studies were made, however, in which a portion of the light fixation and dark release experiment was conducted under simulated Martian conditions. The respiratory activity of soil samples under simulated Martian conditions was assayed subsequent to the photosynthetic fixation of labeled carbon dioxide under terrestrial conditions. Triplicate test samples were light-incubated terrestrially for three hours in the presence of 0.1 microcurie $^{14}CO_2$/ml in a 10 ml chamber. Following exposure to the light, test samples were transferred to the Mars chamber, covered with lithium hydroxide-saturated pads, and incubated in the dark

for a two-hour period. During this time, the LiOH pads were changed at half-hour intervals. Each such change required a brief return to terrestrial conditions. Bard-Parker and dark-incubated controls were provided. The average signal obtained after one hour of dark respiration of the light-incubated samples was about twice that of the dark-incubated and Bard-Parker controls. After two hours of dark respiration, the average light response was still greater than that of either the dark or the Bard-Parker treated samples.

4.0 ENGINEERING PROGRAM

4.1 Engineering Investigations

4.1-A Introduction

In the course of the development of the Gulliver program, it was found that direct application of nutrient media to the ground surface on Earth led to very fast and high biological responses. These responses were measured by using radioactively-labeled medium (Carbon 14) and then monitoring for evolution of radioactive carbon dioxide.

As discussed in the Biology Program section of this report, the moisture maintenance requirement for the wet chemistry presented a major hurdle under anticipated Martian environmental conditions.

1. Study Objectives

The overall objective of the engineering portion of this study was the determination of feasibility of conducting life detection experiments in situ on the surface of Mars in a manner that would permit the incorporation of such experiments into a relatively small instrument package.

The specific objectives of the program included study, experimental, and design phases. During the study phase, current available data on Mars environmental conditions were reviewed with respect to the in situ approach. Liquid water maintenance, water behavior,

water losses, water retention, experimental volume isolation, leakages, biological response detection, and seal effectiveness constituted problem areas receiving particular attention.

The experimental phase involved the acquisition and setting-up of experimental facilities that allowed simulation of the more essential characteristics of the Mars environmental conditions including a Mars soil analog. The work performed in this phase included verification of the information acquired in the study phase and the experimental determination of the behavior of water as a liquid, solid, and gas under simulated Martian conditions. Experimental research into the possibilities of creating and maintaining a moist experiment in situ volume and into its control, maintenance, and dynamic behavior - both over short and long terms - followed. Determination of labeled CO_2 signal detection efficiency under simulated Martian conditions was also included.

Based on results of the study and experimental phases, conceptual engineering design for an in situ life detection instrument was developed.

4.1-B Anticipated Mars Environmental Constraints

In addition to direct communication with NASA and the Jet Propulsion Laboratory, the following were the main sources used in this study of the physical characteristics of Mars:

1. "Mars Engineering Model," NASA, Viking Project, M73-106-0, February 6, 1969.

2. "Mars Scientific Model," Jet Propulsion Laboratory, Document No. 606-1, July 15, 1968.

3. "The Book of Mars," Samuel Glasstone, NASA SP-179, 1968.

Of particular interest to the in situ study was the meteorological and "geological" data regarding atmospheric composition, pressure, temperature variations - both diurnal and seasonal, water vapor abundance, topography, surface material, particle size, porosity, density, and the like. These last surface items are based on the "lunar soil model" established as the model for Mars.

The Martian atmosphere is considered to be composed primarily of carbon dioxide and only trace components of other gases of which water vapor pressure is less than one-hundredth of a torr.

The maximum equatorial daytime temperature lies between (+) 27° C and (+) 30° C according to recent (1969) determinations. The diurnal temperature variation ranges from (+) 30° C to (-) 70° C.

In as much as land features and surface elevation differences may be as high as 8 to 12 kilometers, the surface atmospheric pressure will vary. Six torr, the average surface pressure, was selected for our simulated Martian conditions.

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4.1-C Special Apparatus and Instruments

1. Environmental Chamber Facility

In order to simulate governing parameters for a Mars in situ experiment, it was established early in the program that a vacuum chamber with a high pumping capacity was essential. Major requirements were the attainment and maintenance of very low water vapor partial pressure in the chamber.

The Sunbeam Vacuum Technology Corporation of North Billerica, Massachusetts was commissioned to build an environmental vacuum chamber facility to our specifications including heating and cooling controls and a sufficient number of chamber penetrations to allow insertion of selected gas atmospheres, water, and other liquids during experimentation. The chamber has a 6 inch diameter viewing port and a $1\frac{1}{2}$ inch feedthrough port for electrical and mechanical access. Sections 1.0 through 9.0 of the Sunbeam proposal describing the chamber facility are included here along with catalog information on the high vacuum pump supplied.

SUNBEAM TECHNICAL PROPOSAL Q-1924

1.0 GENERAL

1.1 GENERAL DESCRIPTION

One Sunbeam Environmental Chamber Facility incorporating a 1' x 1' x 1' work area capable of operation at temperatures of -50°C to +50°C. The vacuum system consists of a Welch Model 1398 mechanical pump, which has a rated pumping speed of 53 cfm.

2.0 OVEN AND VACUUM CHAMBER

2.1 VACUUM CHAMBER

The chamber dimensions shall be approximately 20" x 20" x 15" deep. Its inner chamber or shroud will have a 1' x 1' x 1' working area. This inner chamber shall be manufactured entirely of stainless steel, which is inert gas welded for vacuum integrity and highly polished for cleanliness. The inner chamber or shroud will be traced by both cooling lines and heating coils, which will be used to obtain the plus and minus 50°C required, for operation. The inner chamber will then be covered by an insulated material of suitable thickness to insure uniform temperature within the hot zone. This insulation material shall then be covered by a thin mild steel shell. The chamber shall incorporate a completely full opening door for access to the work area; as previously mentioned, the heating and cooling elements shall be placed and correctly attached to the outer surface of the shroud to enjoy uniform heating and cooling throughout the chamber.

The Environmental Chamber shall have a 6" view port on the front door center line for visual observation of the work area. Also incorporated into the Environmental Chamber shall be a 1½" feedthrough port.

3.0 VACUUM SYSTEM

3.1 MECHANICAL PUMP

One Welch Model 1398 fore/roughing pump shall be used, with a rated pumping speed of 53 cfm.

3.2 VACUUM INSTRUMENTATION

One Sunbeam Model 1804 Thermocouple Gauge Control to monitor vacuum preseures in the range of 1 micron to 1000 microns.

4.0 POWER SUPPLY AND INSTRUMENTATION

4.1 TEMPERATURE INDICATION

One Barber Coleman Capacitrol Type Controller shall be used to control the temperatures from -50°C to +50°C within the chamber work area. As previously mentioned heating and cooling will be accomplished by appropriate mechanical refrigeration, cooling lines and appropriate heating coils on outer surface of the shroud.

5.0 PROTECTIVE INTERLOCKS

5.1 HEATING ELEMENTS

SUNBEAM TECHNICAL PROPOSAL Q-1924

5.1.1 Temporary Power Loss

Power to the heating elements is interlocked to prevent damage due to an inrush of current upon restoration of power.

5.2 PUMPING SYSTEM

5.2.1 The mechanical pump and heating and cooling elements are interlocked to prevent operation of the elements unless the mechanical pump is operating.

5.3 Other safety features, including loss of fuses, circuit breakers, etc., in accordance with good vacuum chamber design and operation.

6.0 UTILITY REQUIREMENTS

6.1 ELECTRICAL

5 KVA, 208 volt three phase, 60 Hz.

7.0 OPERATING INSTRUCTIONS

Two complete sets of operating instructions will be provided.

8.0 WARRANTY

8.1 All components, sub-assembly, and total system are guaranteed tight as tested on a helium mass spectrometer type leak detector, peaked to a sensitivity of 2×10^{-10} standard atmospheric cc/second.

8.2 Sunbeam warrants the proposed system against any defects in workmanship or material for a period of one year from date of shipment. Items so found to be defective will be repaired or replaced at the option of Sunbeam, upon notification by the Purchaser and authorization by Sunbeam to return the defective item, prepaid, to Sunbeam, and after verification by Sunbeam of cause of failure.

Excluded from this warranty are the expendable items, such as gauge tubes, mechanical pump fluids, and services and material required for correcting and/or reconditioning malfunctioning equipment resulting from misuse or failure on the part of the user to perform periodic inspection and maintenance services in accordance with accepted good vacuum equipment operating practices.

Excluded from this Sunbeam warranty are those items incorporated in the proposed system of other than Sunbeam manufacture, such as Barber Coleman instrumentation, etc., in which instance the manufacturer's standard warranty will be extended in lieu of all other warranties.

9.0 INSTALLATION

9.1 The Environmental Chamber Facility will be ready for operation upon simple connection to user utilities. The Purchaser is required to furnish all labor and material incidental to system location and connection to utilities, and to supply such other services and utilities as are required for installation and operation of the equipment.

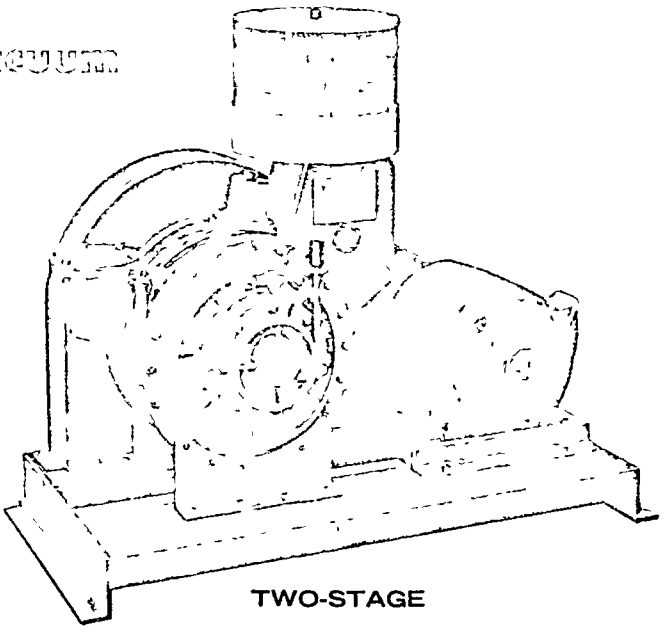
1398M

53 CFM (1500 L/M)

Extra Large Capacity—High Vacuum

A fast, two-stage, oil sealed rotary vacuum pump with adjustable vented exhaust, designed for applications requiring high pumping capacities

The 1398M achieves excellent vacuum characteristics, yet does not sacrifice any of the famous Welch Duo-Seal features, long life, low maintenance, freedom from vibration and minimum noise level An adjustable vented exhaust permits introduction of atmospheric air into the compression cycle to minimize condensation of vapors within the pump



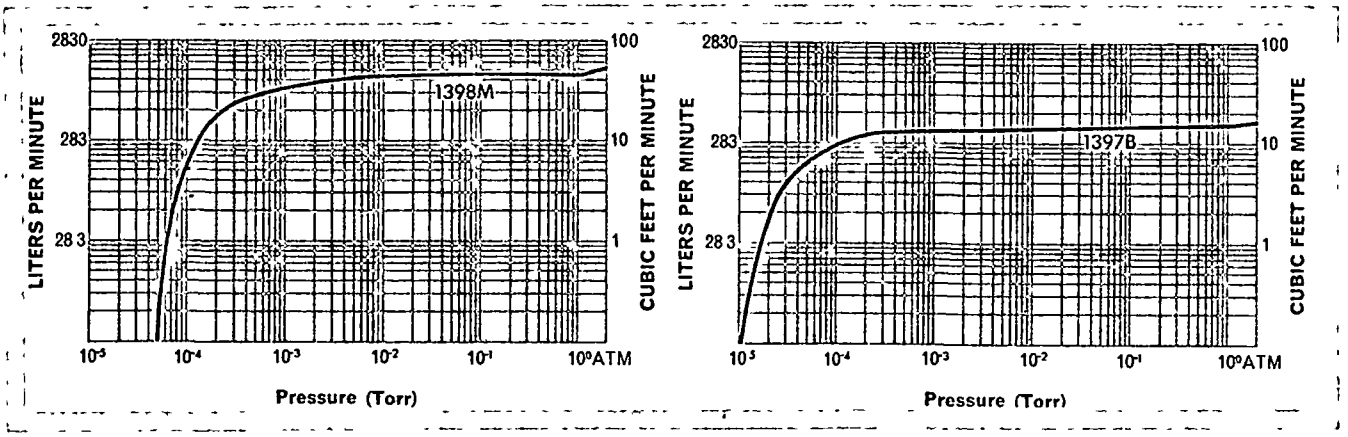
TWO-STAGE

PATENTED

SPECIFICATIONS

Guaranteed ultimate vacuum (with vent closed), 0 1 millitorr, free air displacement, 53 CFM (1500 liters/min), pump speed, 245 r p m, motor, 3 H P, 230/460 V, 3-phase, 60 cycle, flanged, O-ring sealed intake port and intake screen, drive, 4 V-belts, oil capacity, 2½ qts; dimensions, 44" L x 21" W x 37" H, shipping weight 661 lbs, shipping weight, pump only, 430 lbs.

No 1398M
Complete with oil for initial filling and one change, four V-belts, belt guard and motor $1625 00
No. 1398 less base, motor and V-belts. 1350 00



Mars Environmental Simulation Facility.

High Vacuum Mechanical Pump.

	Fig 20		
BIOTHERICS INCORPORATED			
Rockville Maryland	12-69 Date	Init	Scale
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BIOSPHERICS INCORPORATED

2. Other Instrumentation Requirements

Important parameters and ranges of interest were:

(a) Temperature: (-)50° C to (+)50° C
(b) Total gas pressures: 0.001 to 50.0 torr
(c) Partial gas pressure. Water Vapor. Dew point: (-)110° C to (+)20° C
(d) Gas flow: 400 to 50,000 cm^3/min STP
(e) Soil moisture: (differential weighing)

Instruments procured included:

Temperature gauge
Simpson. Model 389. Thermistor probes.

Vacuum gauge
Hastings. Model VT4S2. Serial 3814
Gauge tubes DV-4D

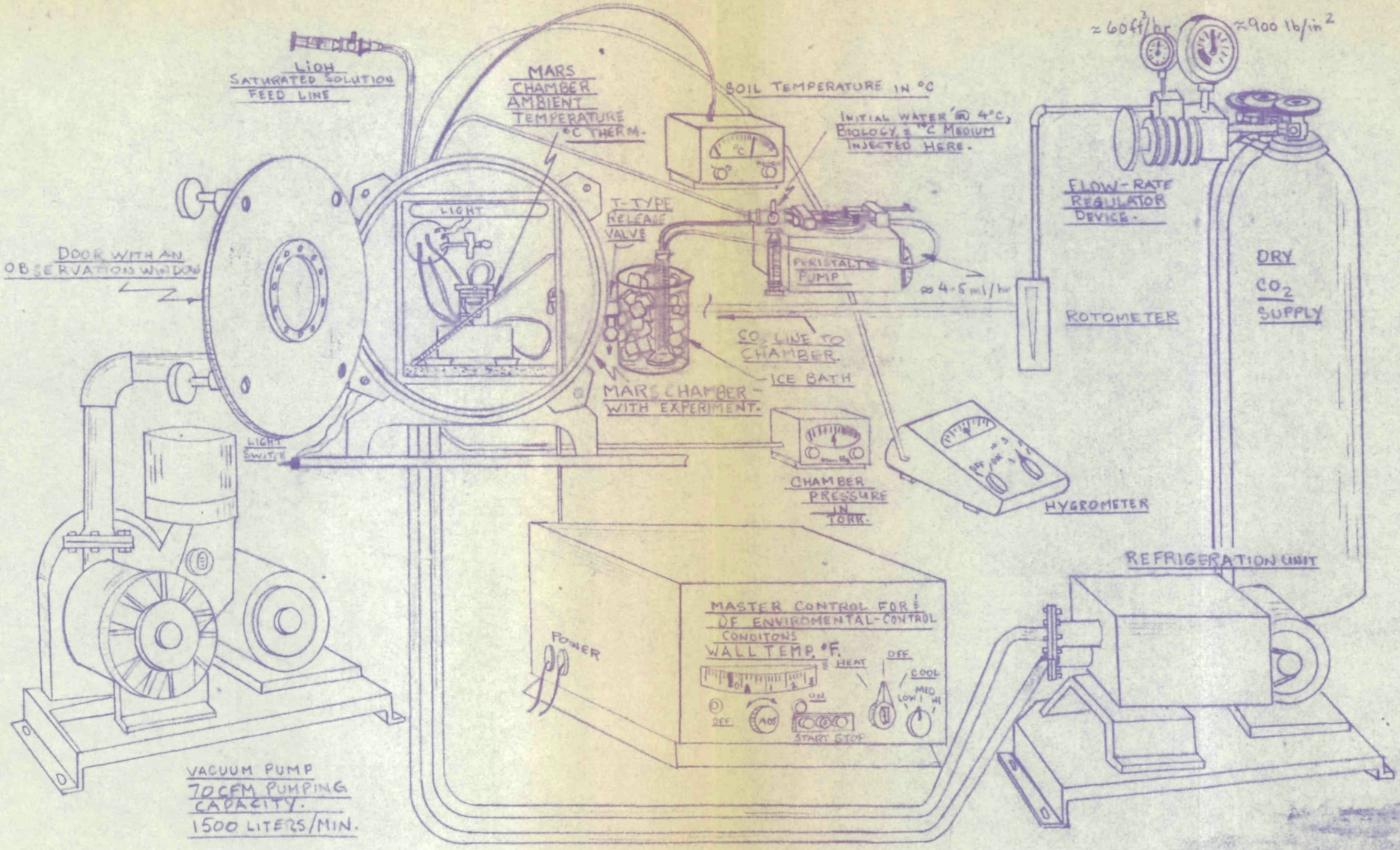
Hygrometer
Panametrics. Model 1000. Serial 6695.
Oxide humidity probes.

Other miscellaneous instrumentation included:
(a) Keith electrometer and vacuum tube voltmeter.
(b) Strip-chart recorder.
(c) Still and movie cameras.
(d) Thermistors, YSI precision thermistors, electric motor timers, switches, and a bell jar and vacuum pump for preliminary determinations prior to delivery of the environmental chamber facility.

4.1-D Mission Constraints

1. Weight, Size, Power, Length of Mission, Experiment Duration.

In addition to the Mars ambient physical constraints on the experiment itself, other constraints are imposed by the mission duration and the payload limitations of the Mars lander vehicle



- B. FORSTER 12/69 -

APPARATUS FOR EXPERIMENTATION DONE UNDER SIMULATED MARTIAN CONDITIONS

BIOSPHERICS INCORPORATED, Rockville, Maryland	Fig. 21		
	Date: 12-69	Init.	Scale
Contr. No. NAS2-5360	Report Title: In Situ Life Detection on Mars		

design. Guidelines were as follow:

Experiment Duration: 3 to 90 Earth days

Size: In situ instrument and lander onboard support equipment and supplies, including connecting umbilical cord to deployed instrument: one cubic foot or less.

Power Requirements: Minimal

Weight: 10 lbs upper total limit, of which approximately 7 lbs for liquids (water, nutrient, other chemicals).

Approximately 1 lb signal processing and control package.

Approximately 2 lbs in situ device, including umbilical cable.

2. Experiment Length Missions and Allowable Rate of Water Loss.

Assuming that the maximum allowable amount of water is 5 lbs, then the allowable loss rate can be determined.

$$5 \text{ lbs } H_2O \doteq 2{,}268 \text{ ml } H_2O$$

For 90 days' experiment:

$$\frac{2{,}268 \text{ ml } H_2O}{2{,}160 \text{ hours}} = 1.05 \text{ ml } H_2O/\text{hour}$$

For 3 days' mission experiment:

$$\frac{2{,}268 \text{ ml } H_2O}{72 \text{ hours}} = 31.5 \text{ ml } H_2O/\text{hour}$$

Therefore:

Experiment	3 Earth days' experiment	90 Earth days' experiment
continuous operation (24 hrs/Earth day)	31.5 ml H_2O/hr	1.05 ml H_2O/hr
half-time operation (12 hrs/Earth day)	63.0 ml H_2O/hr	2.1 ml H_2O/hr
one-third time operation (8 hrs/Earth day)	94.5 ml H_2O/hr	3.15 ml H_2O/hr

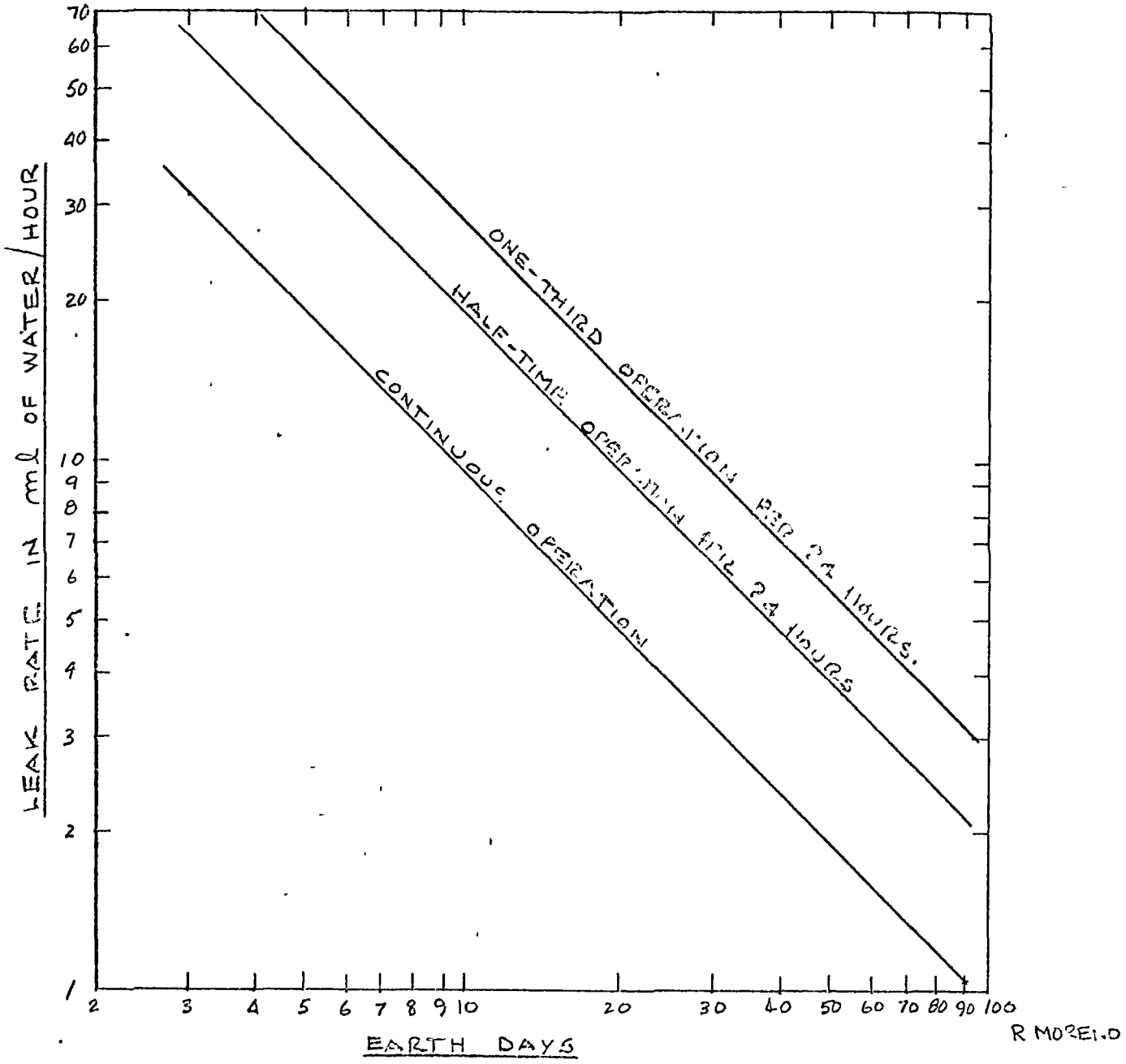
These results are shown in graph form in Figure 22.

4.2 Engineering Program and Experiment Research

4.2-A Moisture Application, Evaporation, Sublimation, and Retention

1. Introduction

Figure 23 tabulates various degrees of water addition, vapor pressure, and anticipated water state. The Viking Biology Team suggested that all degrees of water addition be considered in the operation of an in situ experiment. Water immersion of the sample is considered to impose the greatest environmental change, as far as water is concerned, and, therefore, presents the most hazard to the sample.



Experiment Length Mission and Allowable Rate of Water Loss

	Fig 22			
DI ICS INCORPORATED				
Rockville Maryland	12-69 Date	Ir t	Scale	
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Condition	Water Vapor Pressure	State		
		Ice	Liquid	Vapor
1. Ambient Martian Conditions	$\leq 10^{-2}$ torr	none	none	all
2. Added Water Vapor	$\leq$ 4 torr	none	none	all
3. Added Ice	$\leq$ 4 torr	yes	none	yes
4. Added Water Vapor Plus Spray of Micro-droplets	$\leq$ 20 torr	frost possible	micro-droplets	yes
5. Added Liquid Water to Soil Saturation	$\geq$ 20 torr	yes	yes	yes
6. Added Liquid Water beyond Soil Saturation to Pooling	$\geq$ 20 torr	yes	yes	yes

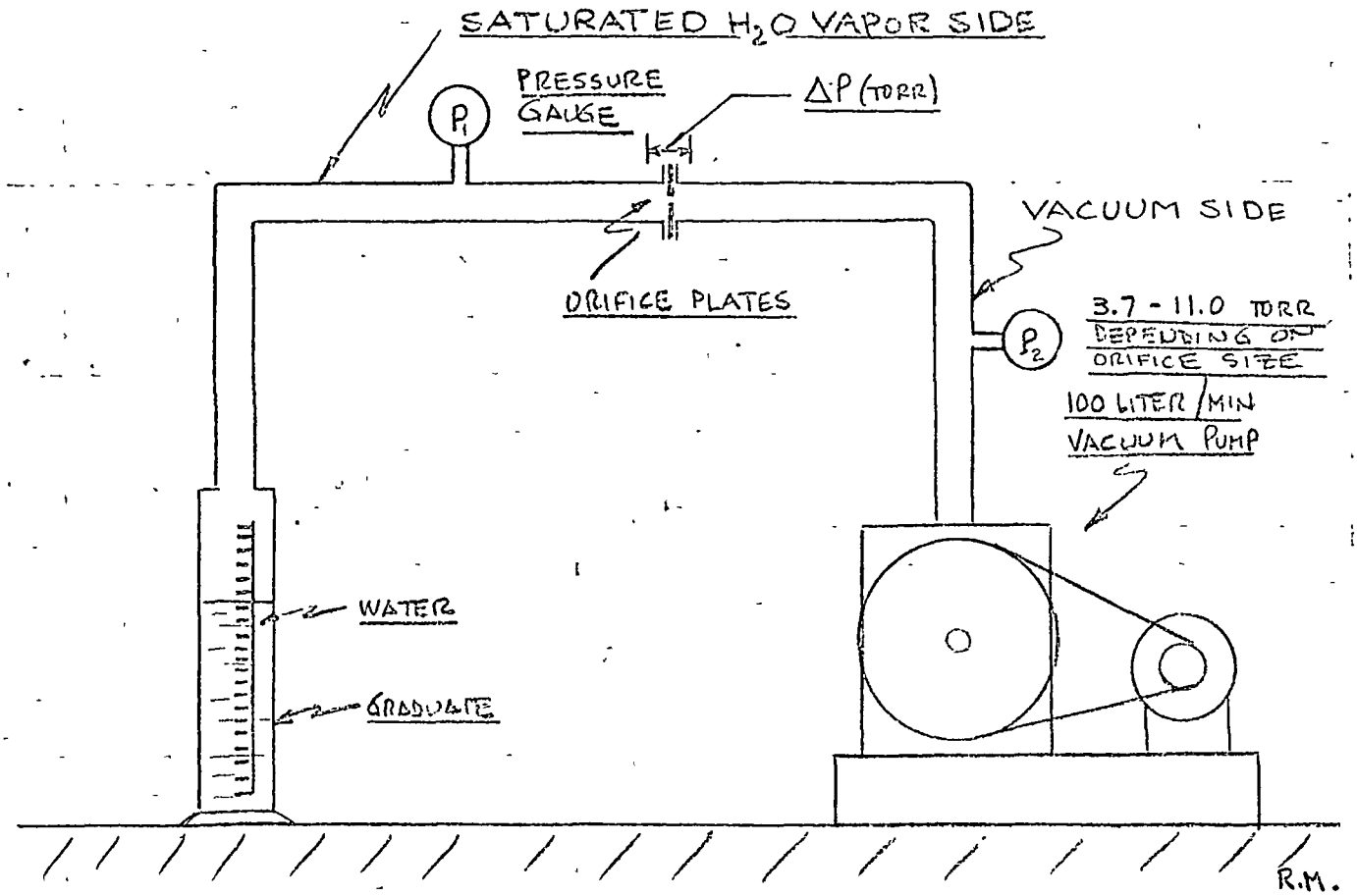
Degrees of Moisture Level Conditions,
Water Vapor Pressure, and Anticipated Water State
in the Immediate Vicinity of
Experimental Volume on Mars Surface

2. Water Vapor Leak Rates Under Mars-Like Conditions

The experimental set-up shown in Figure 24. was used to determine leak rates through an orifice from a volume of saturated water vapor into a volume at a lower pressure.

In order to arrive at a mathematical prediction of leak rates, the following procedure was followed:

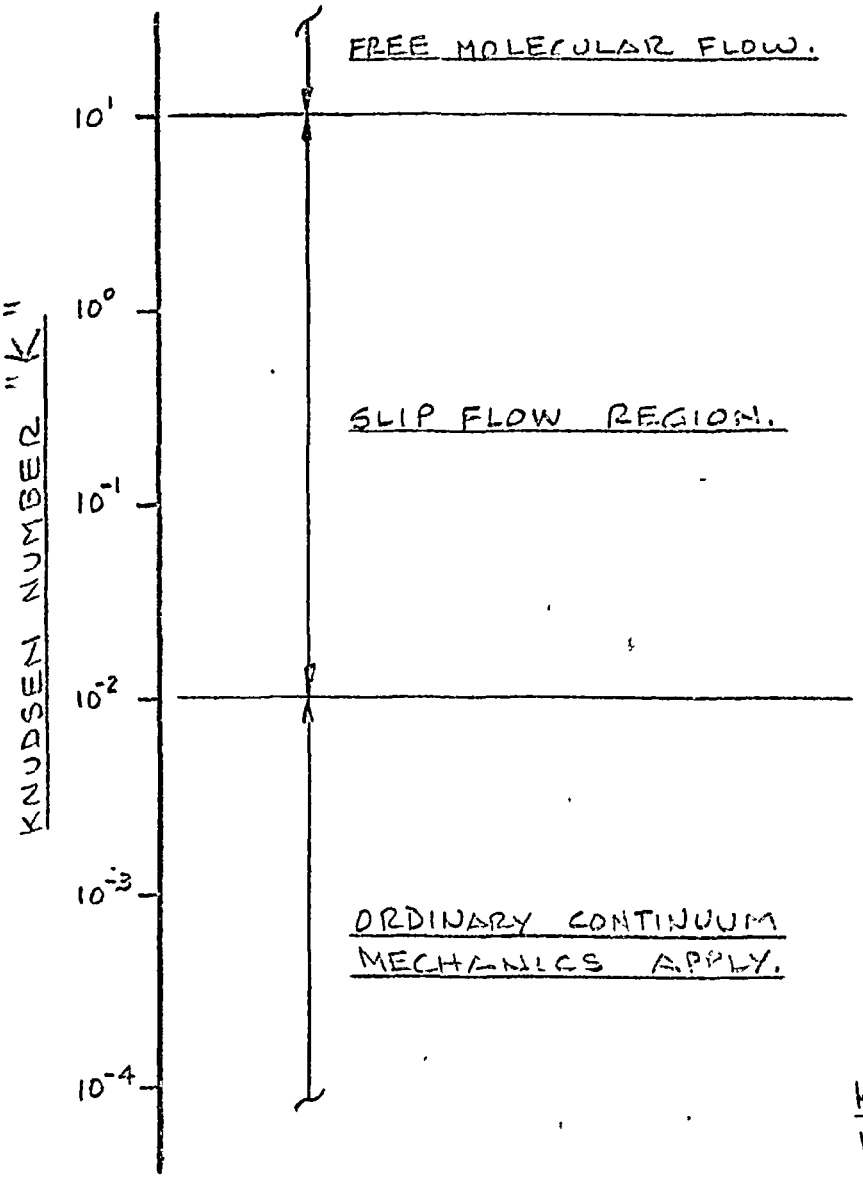
From rarified gas dynamics, the Knudsen number, "K," was calculated in order to determine the gas flow regime under the pressure conditions. The regime scale in terms of "K" is shown in Figure 25.



SCHEMATIC OF EXPERIMENTAL SET-UP FOR THE DETERMINATION OF WATER VAPOR FLOW-RATE THROUGH ORIFICES UNDER LOW PRESSURES.

R MORENO

BIOS INCORPORATED Rockville Maryland	Fig 24		
	12-69 Date	Init.	Scale
No S2-5360 Cont No	In Situ Life Detection on Mars Report Title		



$\lambda_{H_2O} = 3.15 \times 10^{-4}$ CM
AT 15°C

K = KNUDSEN No.

$K = \frac{\lambda}{d}$

λ = MEAN FREE PATH (CM)

d = AVERAGE DIMENSION OF CONTAINER OR APPARATUS.

Regime Guidelines

Knudsen Number "K"

R. MORENO

	Fig. 25			
GI ICS INCORPORATED				
Rockville Maryland	12-69 Date	Int	Sect.	
NAS2-5560 Cont. No.	In Situ Life Detection on Mars Report Title			

BIOSPHERICS INCORPORATED

For $K = \frac{\lambda}{d}$

Then: λ (the mean free path for water vapor) $= \frac{kT}{\sqrt{2\pi} P\sigma^2}$

Where: σ = molecular diameter, cm.

$k = 1.38 \times 10^{-16}$ dynes/cm/°C

T = absolute temperature

P = pressure in millitorrs

λ = m.f.p. in centimeters

Assuming:

ambient temperature = 288 °K (the recommended upper limit for Viking biology experiments)

$\sigma = 4.6 \times 10^{-8}$ cm

Then: at 2.38×10^4 millitorrs

$$\lambda_{H_2O\ Vapor} = \frac{(1.38 \times 10^{-16})(2.88) \times 10^2}{(2.51)(2.38 \times 10^4)(21.1) \times 10^{-16}}$$

$\lambda_{H_2O\ Vapor} = 3.15 \times 10^{-4}$ cm

Or, in inches:

$\lambda_{H_2O\ Vapor} = 1.24 \times 10^{-4}$ inches

BIOSPHERICS INCORPORATED

Let "d" the average dimension of the apparatus be 6 cm

Then: $K_{water} = \frac{3.15 \times 10^{-4}}{6 \text{ cms.}}$

Obviously: $K \ll 10^{-2}$

and, therefore, according to the guideline for gas flow, the applicable regime is that of ordinary continuous mechanics.

Since ordinary continuous mechanics apply to steam dynamics, the empirical equations of steam flow (M) were tested:

Napier's equation: $M_N = \frac{P_1 A}{70}$ lbs/sec

Grashof's equation: $M_G = 1.65 \times 10^{-2} P_1^{0.97} A$ lbs/sec

Rateau's equation: $M_R = (16.367 - 0.90 \log P_1) \times 10^{-3} A$ lbs/sec

where P_1 is the net driving force (pressure) and A is the orifice area.

Assuming the net water vapor leak driving force to be that of the saturated volume into the Mars atmospheric pressure, then let

$P_1 = 23.28$ torr $= 31.35$ millibars

Assuming a constant P_1 and varying only the leak orifice area:

$$P_1 = (31.35 \times 10^{-3} \text{ bars})(9.6 \times 10^{-1} \frac{\text{atmospheres}}{\text{bar}})$$

$$= 46 \times 10^{-2} \text{ psi}$$

Then steam flow prediction equations can be written as:

Grashof's equation: $M_G = (5.5 \times 10^{-3})(A\ in^2)$ lbs/sec

Napier's equation: $M_N = (6.57 \times 10^{-3})(A\ in^2)$ lbs/sec

Rateau's equation: $M_R = (9.09 \times 10^{-3})(A\ in^2)$ lbs/sec

It is evident that for each orifice area, the Napier equation gives values lying between those given by the Grashof and the Rateau equations. Figure 26 shows the results obtained with Napier's formula after conversion from pounds water vapor/per second to grams water/per minute.

It can be seen that Napier's equation provides a good, conservative approximation for computing leak rates of water vapor through various leak areas.

3. Martian Soil Model

Loss rates of water liquid or water vapor through the soil on Mars are unknown. In order to be able to determine experimentally the behavior of water in soil under simulated Martian conditions, it was necessary to establish a Martian Soil Model.

The Viking Mars Engineering Model (NASA M73-106-0) 1969 recommends the approximation of Mars soil characteristics to those of lunar soil. The Mars Scientific Model (JPL 606-1) tabulates the cumulative percentage of particle size distribution on the surface layer of the accepted lunar soil model. The distribution given is shown in graph form in Figure 27. The clay, silt, and sand regions indicated are

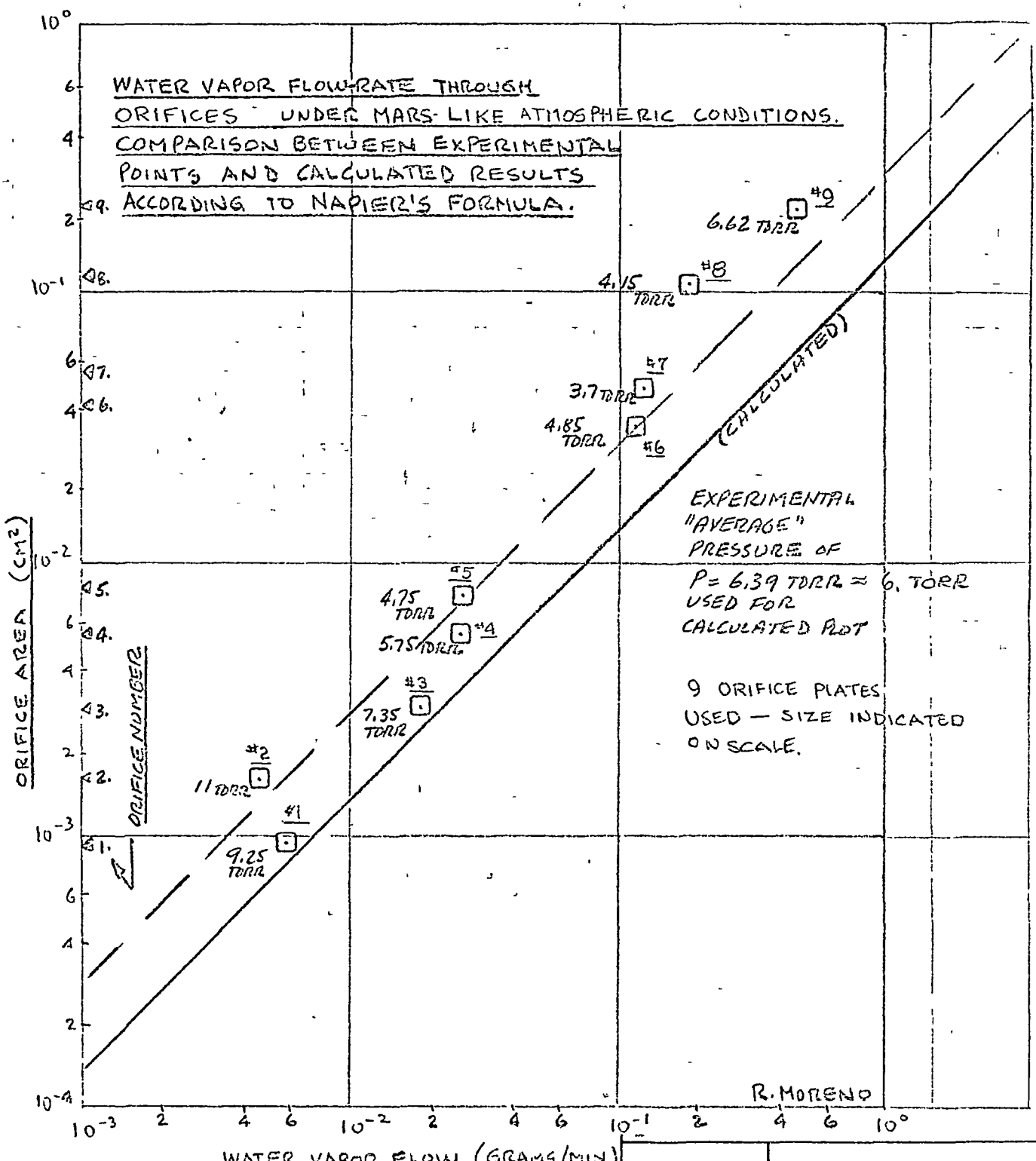


Fig 26			
BIOMEDICS INCORPORATED Rockville Maryland			
	12-69 Date	Init	Scale
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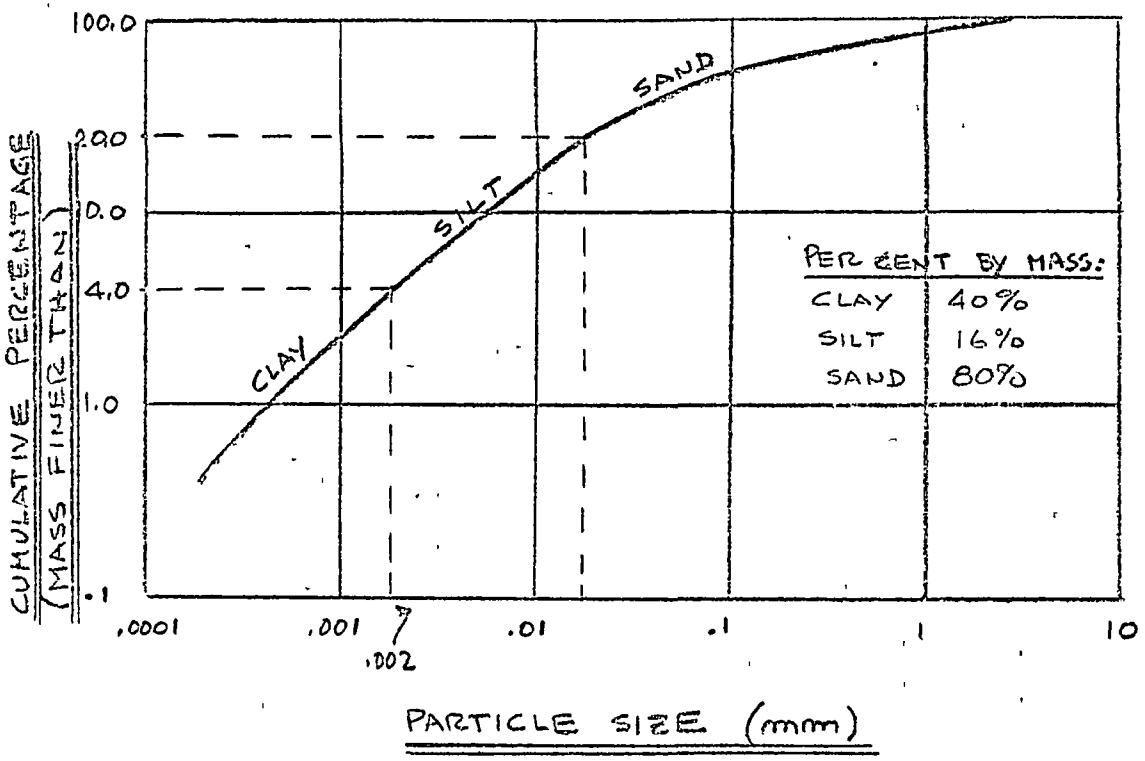

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Cumulative Percent of Particle Sizes in Lunar Model Soil

R. MORENO

BCS INCORPORATED Rockville Maryland	Fig 27		
	12-69 Date	Init.	Scale
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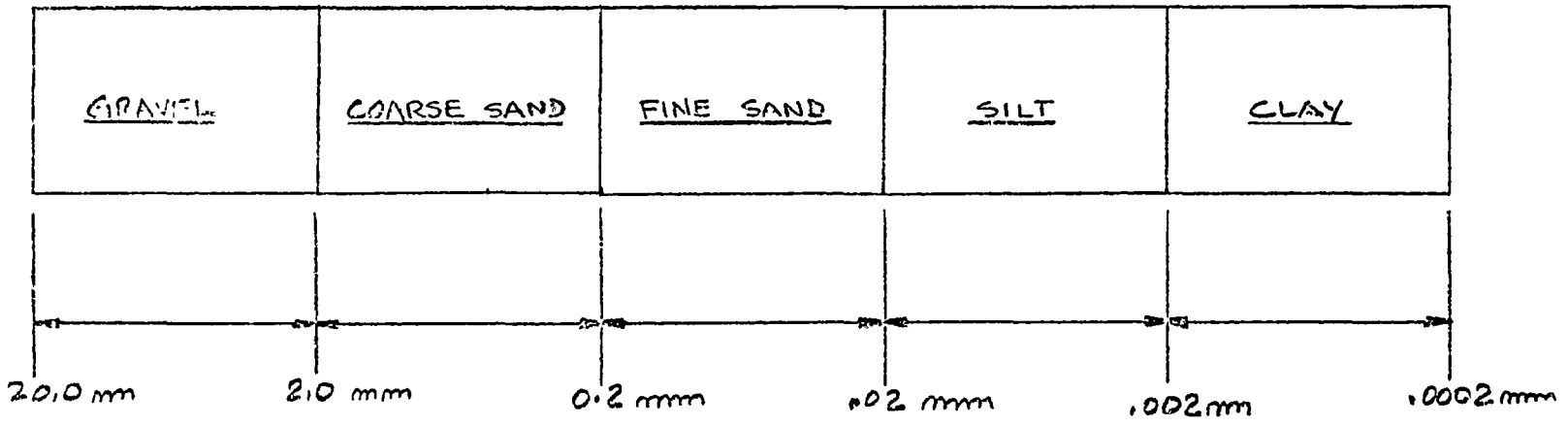
based on the classification of soil particles by the International Society of Soil Science, shown in Figure 28. According to the United States Department of Agriculture classification of Earth soils by soil texture, it was determined that the Earth soil coming closest to the lunar accepted soil model comes under the classification of "loamy sand." Figure 29 shows the diagram for textural soil classification.

From the above considerations, it was assumed that use of a loamy sand soil could serve as a Martian soil model for the purposes of experimental determinations under simulated Martian conditions. Incidentally, it is important to understand that the textural name "loamy sand" describes particle size distribution only and should not be construed as representative of the popular concept of loam as a soil containing organic material. The source of the loamy sand for the experimental program has been the Soil Testing Laboratory on the University of Maryland.

4. Moisture Retention

A phase diagram for water clearly shows that at the anticipated atmospheric pressure and temperature ranges on Mars, water will not exist stably in the liquid or solid phases.

Liquid water introduced into the simulated Martian environment verifies this. Liquid water introduced at a temperature above the boiling point - for example, at 6 torr atmospheric



Classification of Soil Particles by the International Society of Soil Science

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	Fig 28
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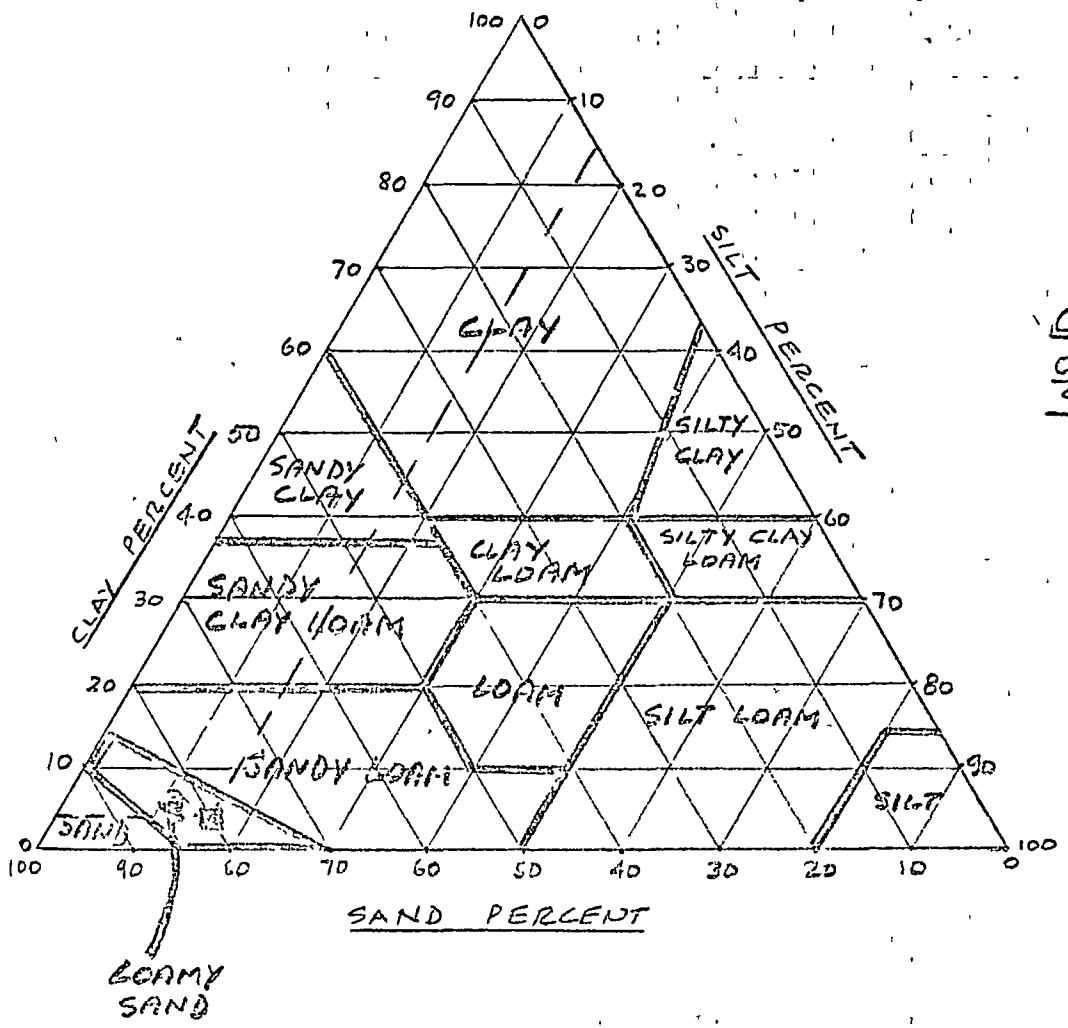
Cont No NAS2-5360	Report Title In Situ Life Detection on Mars



COMPONENTS OF LUNAR MODEL SOIL:

CLAY	4%
SILT	16%
SAND	80%

DIAGRAM FOR DETERMINING TEXTURAL NAME OF SOILS. U.S.D.A.

R MORENO

Fig 29

CS INCORPORATED

Rockville Maryland | 12-69 Date | Init | Scale

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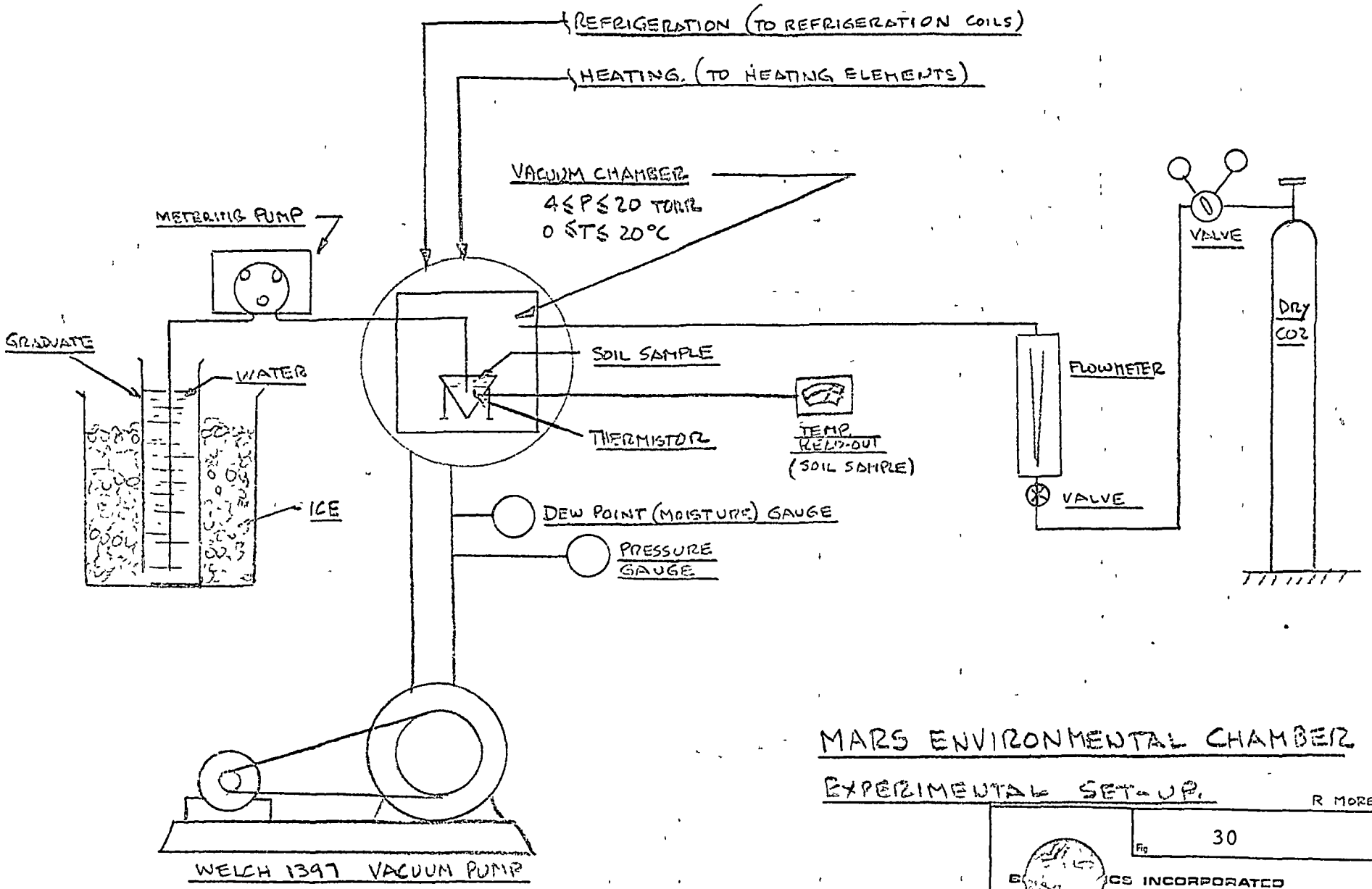
pressure, will boil violently. Liquid water at below the boiling point at 6 torr will evaporate rapidly in an attempt to attain its water partial vapor pressure at this atmospheric pressure. In this process, the liquid water loses internal energy. When the energy loss is sufficient to cool the remaining liquid water to 0° C, the water freezes at all exposed evaporation surfaces.

As the water cools down, the partial vapor pressure of water is reduced, and the rate of evaporation is consequently reduced. Upon freezing, the evaporation or "sublimation" process continues until all encapsulated water is frozen; and then, as the ice temperature continues to drop, sublimation continues until all the water is introduced into the vapor stage.

Several experiments were performed under simulated Martian conditions in order to determine the amount of water retained by the Mars model soil after subsurface application. The experimental set-up is shown in Figure 30.

The soil under test was oven-dried and then cooled in a sealed container before being used in the experiment. A record of total water addition to the soil by means of a subsurface applicator was kept. At the end of each experiment, the soil was weighed before and after drying (at 180° C for 2 hours) for moisture loss determination. The results for the various test runs are shown in Figures 31, 32, 33, 34, and 35.



MARS ENVIRONMENTAL CHAMBER

EXPERIMENTAL SET-UP.

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Fig 30

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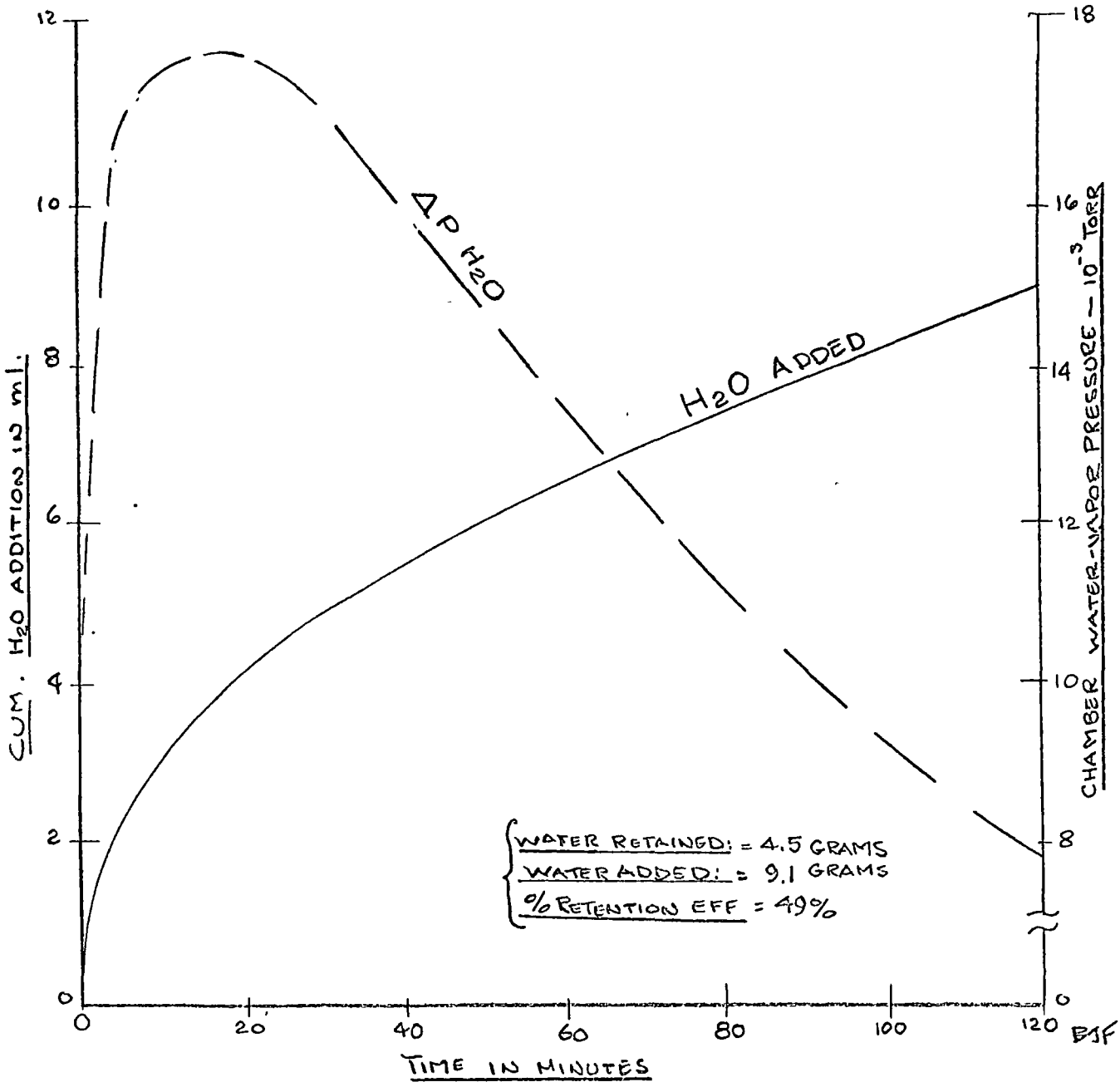
NAS2-5360 | In Situ Life Detection



CAPILLARY APPLICATOR TESTS USING A LOW RATE OF H_2O ADDITION

	Fig 31		
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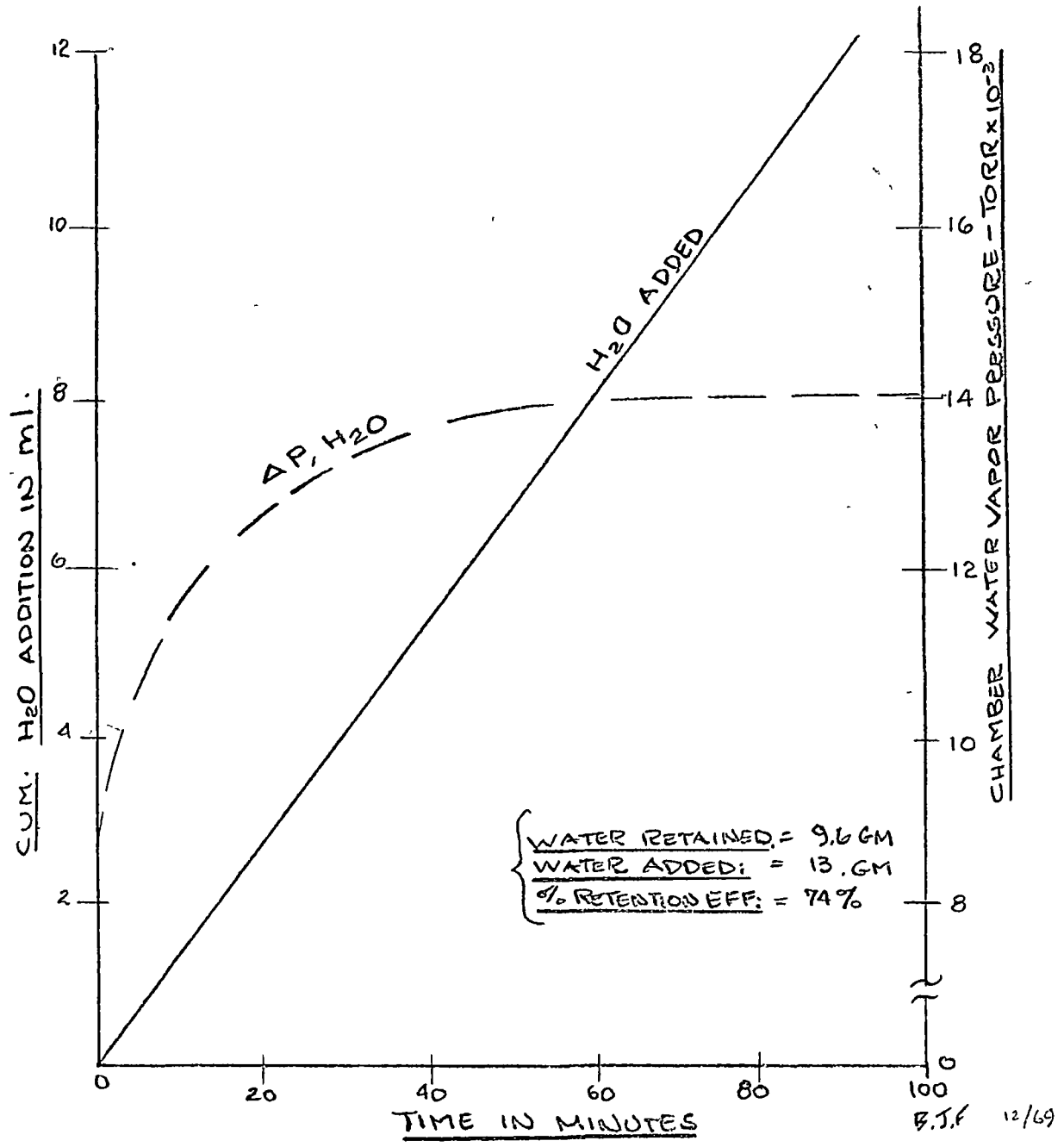

CAPILLARY APPLICATOR TEST RESULTS
USING HIGH RATE OF WATER ADDITION:

Rockville Maryland	Fig 32		
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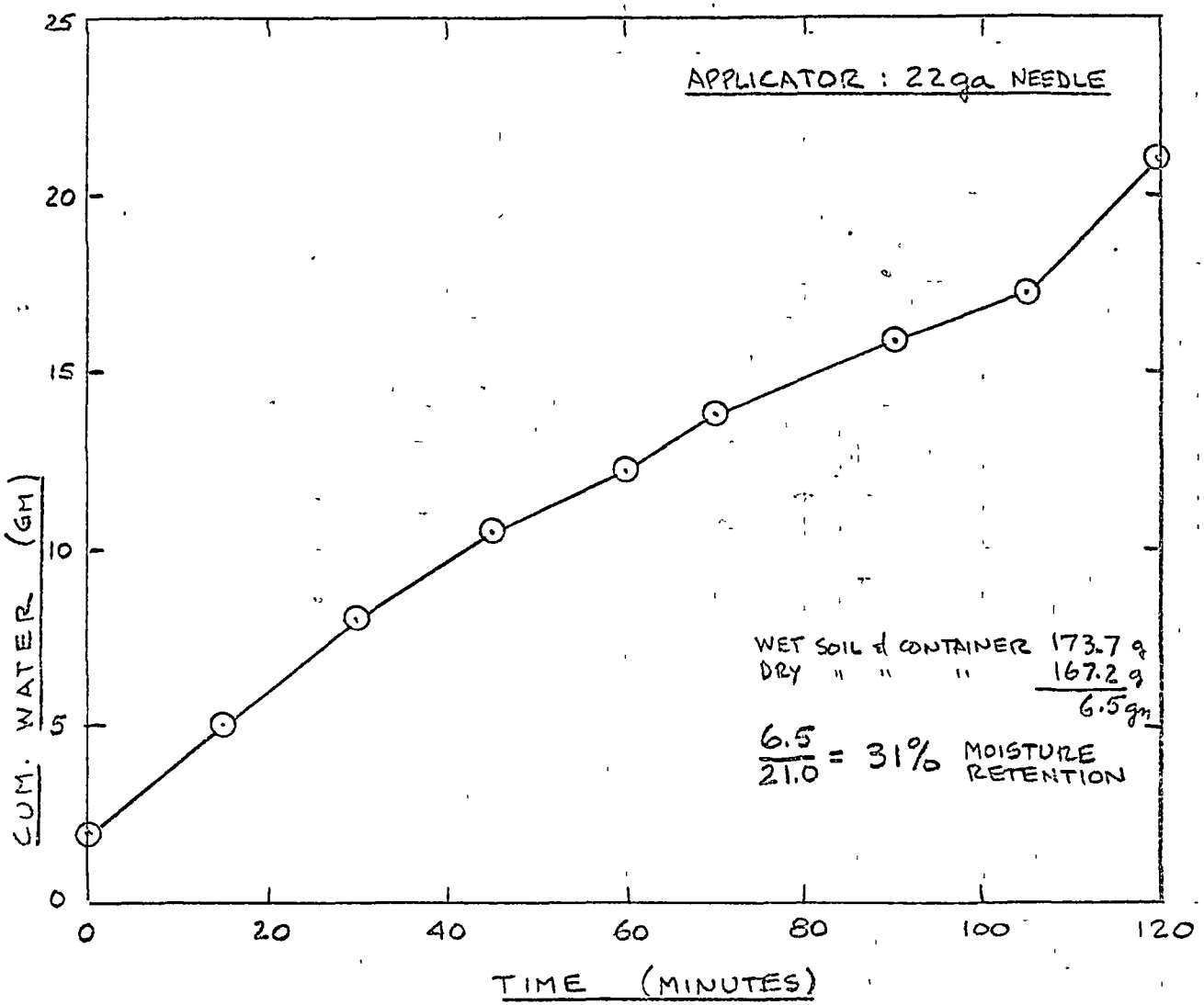


MOISTURE RETENTION IN SOIL AS A FUNCTION OF RATE OF APPLICATION TO FORM AN ICE BALL.

R MORENO

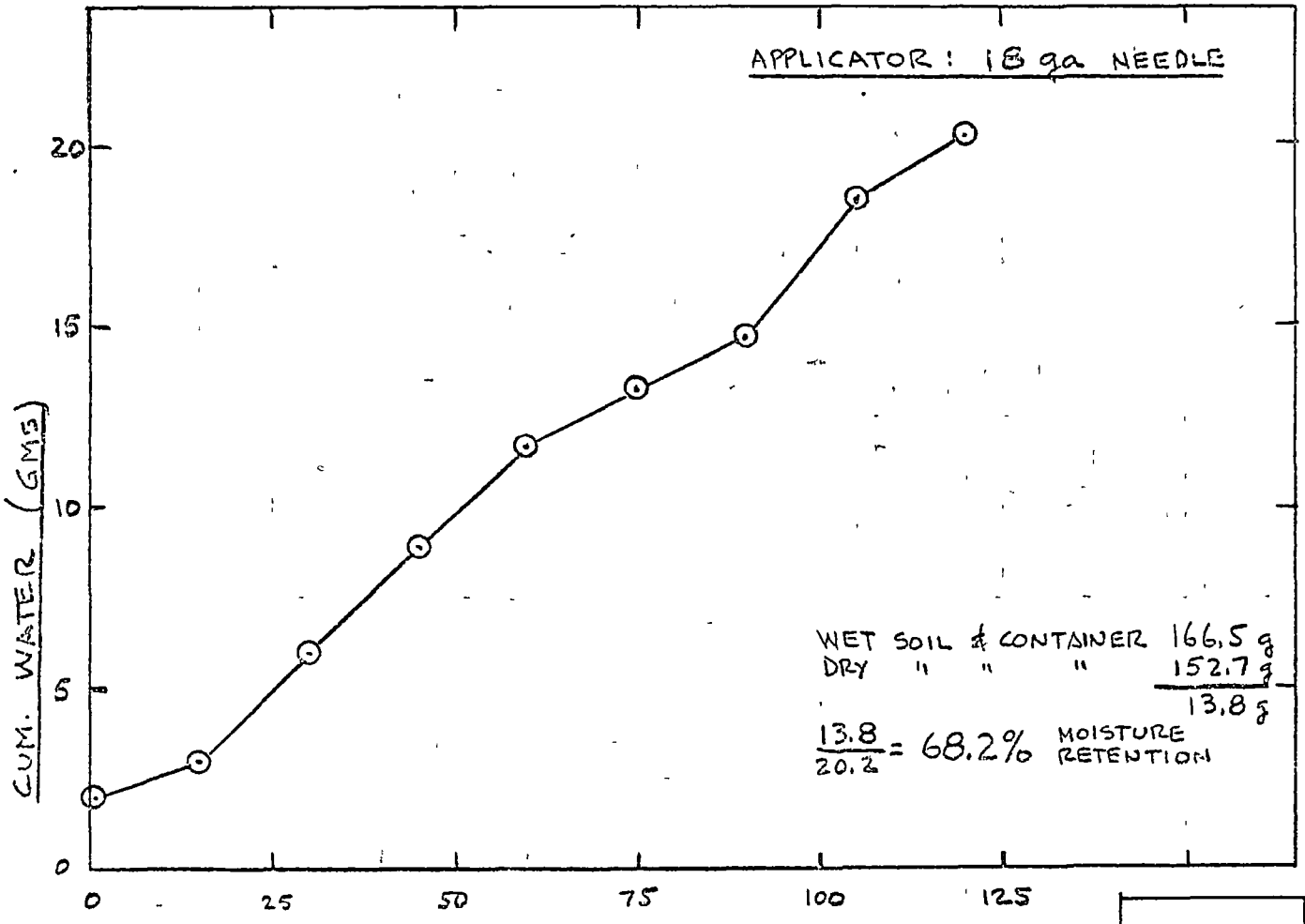
Fig 33

BIOTICS INCORPORATED

Rockville Maryland

12-69 (Date) | (Init) | (Scale)

NAS2-5360 | In Situ Life Detection on Mars



THE MOISTURE RETENTION IN SOILS AS A FUNCTION OF RATE OF APPLICATION — TO FORM AN ICE BALL.

R. MORENO

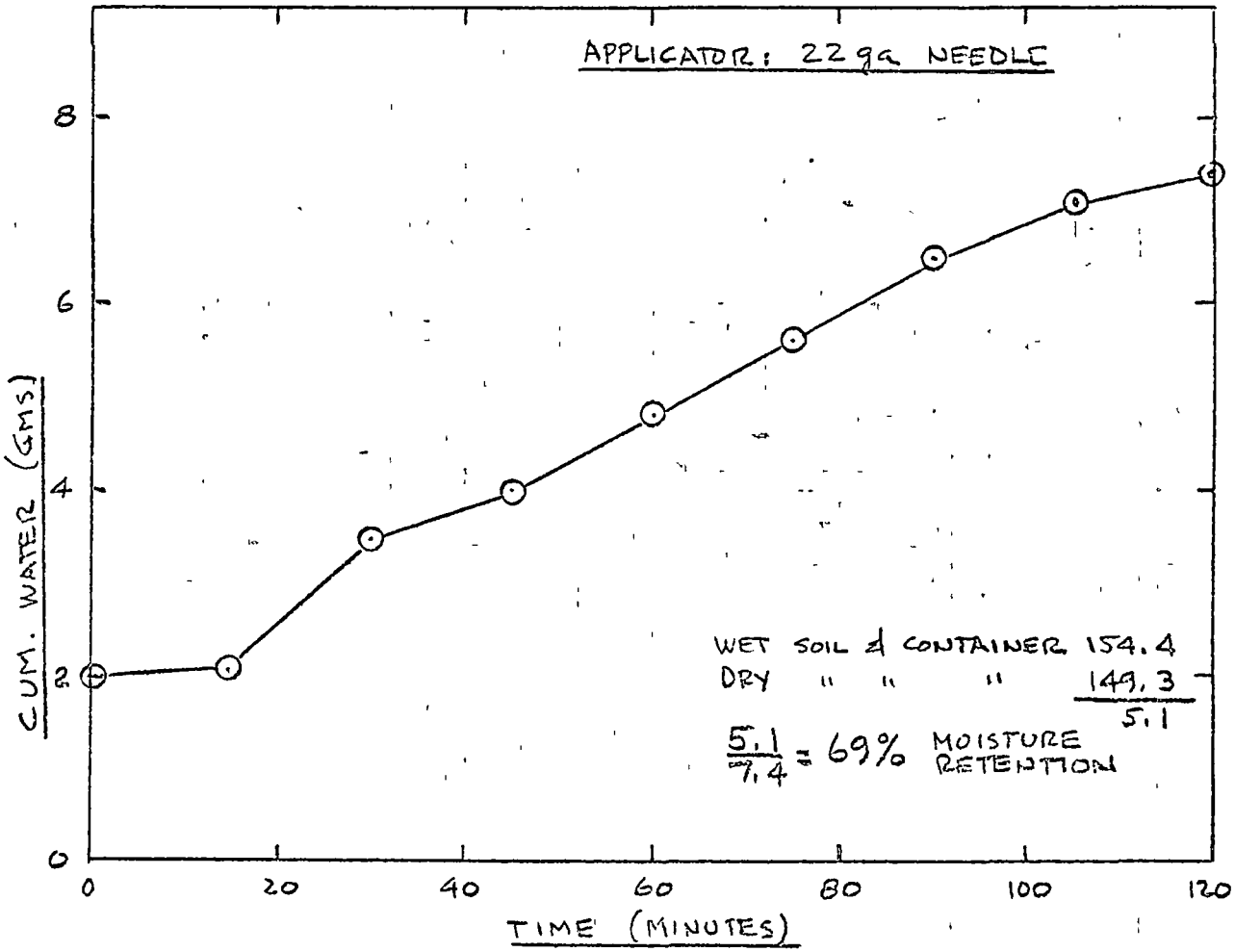
Fig 34

BIONICS INCORPORATED
Rockville Maryland

12-69 (Date)

NAS2-5360

In Situ Life Detection on Mars



MOISTURE RETENTION IN SOILS AS FUNCTION OF RATE OF APPLICATION TO FORM AN ICE BALL

R. MORENO

Fig 35

ECS INCORPORATED

Rockville Maryland

12-69 Date | Init. | Scale

NAS2-5360 | In Situ Life Detection On Mars

BIOSPHERICS INCORPORATED

Mars environmental conditions were simulated by the following in the Mars environmental chamber:

Atmosphere:	CO_2
Atmospheric Pressure:	6 torr
Ambient Temperature:	10-15° C
Pumping Speed:	1500 liters/min
Dew Point (initial):	(-)50° C (equivalent to a partial pressure of water vapor of less than .02 torr)
Soil Temperature:	approx. (+)4°C
Dry CO_2 Addition	Continuous as required to maintain 6 torr in the chamber

Water injection was maintained by means of a peristaltic constant volume pump. The approximate water temperature upon injection to the soil is estimated at about 4° C. A 1/32" I.D. tube was used for delivery to a capillary water injection tube driven just below the soil surface.

4.2-B Water Loss Reduction

1. Introduction

Experiments were performed to investigate the possibility of reducing water loss and hence improve water economy during in situ experiments under simulated Martian conditions.

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The rate of evaporation loss from liquid water or from ice is directly proportional to the exposed free area. Thus, evaporation losses can be reduced by controlling the rate of water supply to that just sufficient to maintain the initially formed ice ball.

Another way to improve water economy for a particular mission would be intermittent operation of the experiment as opposed to continuous operation. In this way, the experiment and water supply requirements could, for example, be reduced to one-half or one-third of that required for continuous operation.

The experiments performed were not related to the above obvious approaches, but were designed to investigate intrinsic water loss reduction. Hygroscopic or hydrophylic materials, semipermeable membranes, soil sealants, and gels were investigated for usefulness in reducing water losses from the in situ volume.

Although some substances, particularly gels, appeared initially to offer some promise, the overall results were disappointing.

A description of several of the experiments and the observed results follows:

2. Gels

Gelling substances are hydrophilic; that is, they hold water molecules when they form a "gel." This behavior has been explained by various models, one them being that water

is held in the capillary spaces formed by the molecular structure of the gel. At any rate, to test this ability of gels, an experimental arrangement consisting of three small beakers was placed in the Mars environmental chamber. Each beaker contained approximately 30 grams of one of the following:

a. ice

b. "cold" set jello (originally at about 10° C)

c. "frozen" set jello (originally at about -5° C)

The atmospheric pressure was maintained at 6 torr, and the test was run for 18.5 hours.

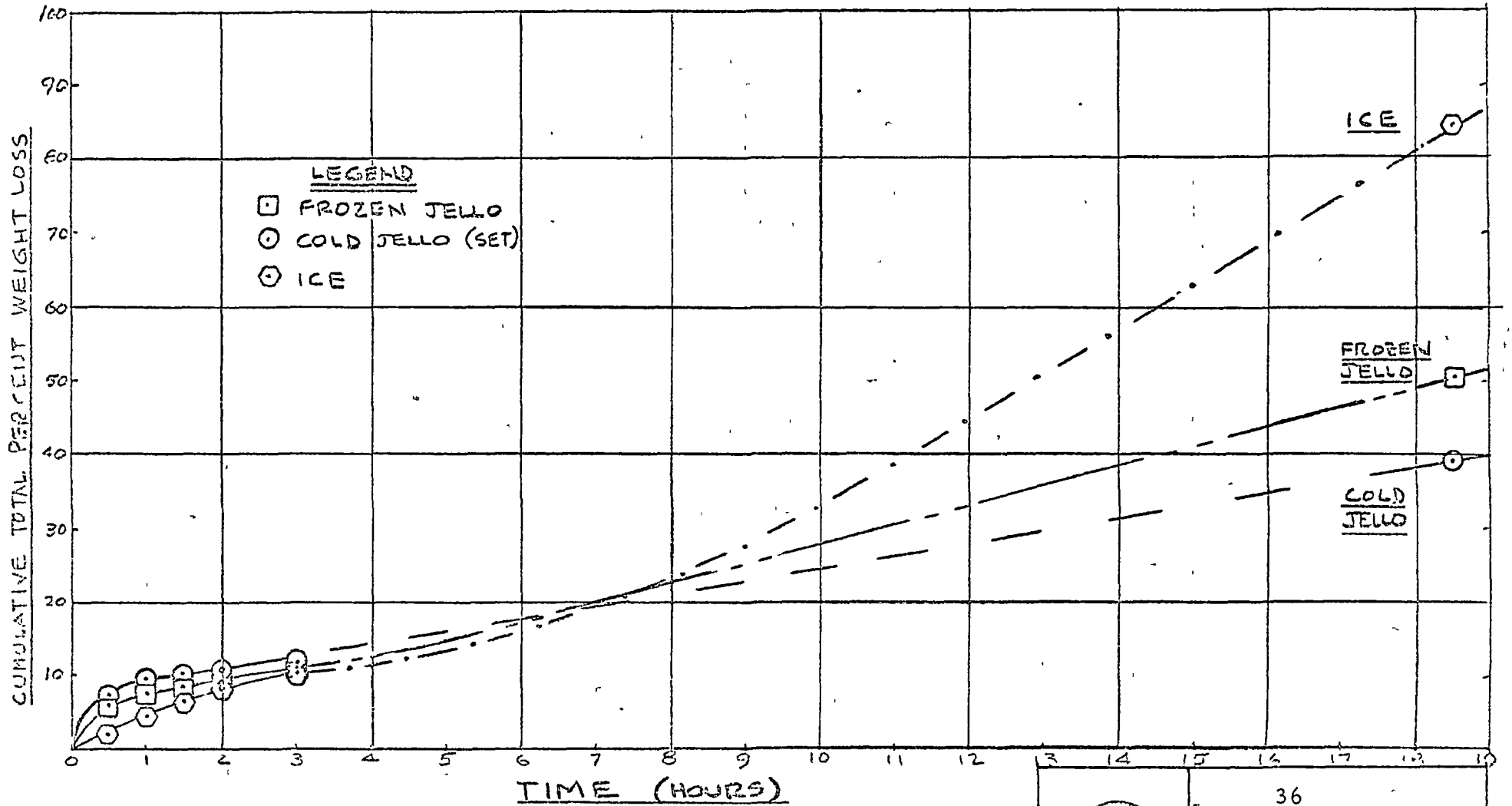
The results of this experiment are shown in Figure 36. It can be seen that the gels held water longer than ice. It should be noticed, however, that the initially "frozen" gel did not hold onto the water as well as did the initially "cold" (but not frozen) gel although the latter froze a few minutes after the start of the test.

Water released from gels under these conditions is in the form of vapor. The heat lost through evaporation cools the exposed surface of the gel and causes freezing.

It appears that the ice seal gel gets better with time as additional ice forms and the temperature drops further. From the graph, it appears that the ice, or frost, formed rapidly in the

100% WEIGHT: APPROX 30 grams EACH.
EVAP. SURFACE AREA: 33.6 CM^2 EACH.

PERCENT OF WATER WEIGHT LOSS UNDER VACUUM (6 TORR) AND CO_2 ATMOSPHERE VS TIME.



COMPARISON OF MOISTURE LOSS UNDER MARS SIMULATED CONDITIONS FOR ICE AND GELS

BIOCS INCORPORATED Rockville Maryland	Fig 36		
	12-69 Date	Init	Scale
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capillaries of the gel structure under vacuum gives a better seal than ice formed slowly in the gel when "frozen" at Earth ambient pressure.

2.1 Wetting by Means of Gels

To see whether or not gels release liquid moisture under vacuum enough to wet dry soil, a sample of dry Mars model soil was placed in a small beaker in the Mars environmental chamber and allowed to cool to about 0° C to prevent liquefaction of the gel surface when placed in contact with the soil.

A sample of gel whose "set" point was about 5° C was cooled to about 1° C to avoid liquefaction of the surface during handling procedures. Utensils which were in contact with the gel were also cooled to avoid liquefaction of any part of the gel. Once the gel was placed on the soil, the chamber was evacuated to a pressure of 6 torr of CO_2 atmosphere.

When the cold gel at 1° C was placed in contact with dry deaerated soil at the same temperature in the Mars environmental chamber with 6 torr of CO_2, the following observations were made:

a. The gel developed frost on the outside surface after initial deaeration.

b. After the surface exposed to the atmosphere frosted over, apparently the

evaporation was channeled primarily to the underside at the soil-gel interface. The soil became disturbed.

c. A control beaker of the same soil placed in the chamber next to the gel-soil set-up remained unaffected. Therefore, the soil disturbance in "b" was not due to the Mars environment effect on the dry soil but to channeled flow of water vapor as assumed.

d. The gel continued to frost until it was completely frozen in less than 20 minutes.

The gel did not appear to wet the soil. There was no evidence that the gel let liquid water out of its structure when set on the soil surface. Apparently, moisture at the surface of the gel evaporated directly into the atmosphere rather than being retained in the soil.

2.2 Feasibility of Re-supplying Water to Gels Under Reduced Atmospheric Pressure (Martian Simulated Conditions)

At about the time when gels were proposed as a means of regulating moisture release rates, it was suggested that partially dehydrated gels may be re-supplied with water vapor. "Elastic" gels are known to regenerate after dehydration if resupplied with water

before they are completely dried up, as opposed to "inelastic" gels which will not.

A preliminary analysis of the conditions in the Mars chamber indicated that this would not be feasible since the water vapor pressure gradients were unfavorable. However, for the sake of verification, various re-supply schemes were investigated. These included re-supply by:

a. Small bore tubing (hypodermic needle),

b. Membranes in contact with the gel,

c. Fiber matrices imbedded simultaneously in gel at one end and in a water source at the other end.

Results:

a. By small bore tubing - A gel fitted with a capillary applicator to attempt to introduce water into the gel was placed under vacuum at 10 torr. The water did not "soak" into the gel but instead escaped through the space around the capillary applicator where the penetration had been effected. Capillary application of water to gels does not appear to be a workable method for gel regeneration.

b. By membranes in contact with the gel - Uncoated cellophane and General Electric Co. membrane MEM-213 were investigated.

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The preliminary experimental set-up consisted of cylindrical containers about 6 cm in diameter, 15 cm in height, and open at both ends. One end was then covered by the membrane under observation. The membrane was held in place by a cementing material applied to the edge of the cylinder (whose wall thickness was approximately 1/8 of an inch) and by physically wrapping several turns of strong rubber bands over that part of the membrane draping over the outside of the cylinder. The cylinder was then filled with water and closed at the other end, with a balloon to allow for expansion of water vapor and gases which were entrapped in the water.

The cylinders were then placed with the membrane end held firmly against the surface of a gel which had been poured into petri dishes and allowed to dry for several weeks.

This set-up was then placed in the Mars environmental chamber and pumped down to 6 torr of CO_2 atmosphere.

Results:

1. Cellophane - In this preliminary test, it was observed that the cellophane membrane allowed water to flow onto the gel. The rate was faster than expected, which may have been caused by pinholes which developed during the course of the testing. The water froze on the outside surface of the membrane, and a self-sealing effect was evident. Hence, the surface area available for

water transmission through the membrane was reduced considerably by this freezing. It was soon evident that the ice was sublimating faster than any water which might have been coming out of the membrane despite the holes. Subsequent observation of the gel showed only superficial evidence of regeneration in that it looked shiny at the area of contact with the membrane. The gel surface did not appear tacky, nor were there any indications that the gel was imbibing or being replenished with water at a rate that might have been considered of interest for the purpose under consideration.

2. G.E. Membrane MEM-213 - The sample used for this experiment was thicker than the cellophane sample used for the previous experiment. The thickness of the MEM-213 was 3 to 3.5 mils, and the cellophane 1 to 1.5 mils.

In this test there was no gross evidence of water transmission through this particular membrane. Subsequent examination of the gel did not show any evidence of wetting.

c. By fiber matrices imbedded in the gel and in a water source (wick) -

Cotton fibers were partially immersed in a gel which was then allowed to "set." The free end of the cotton was immersed in water, and the arrangement was placed in the Mars environmental chamber and pumped down to 6 torr and CO_2 atmosphere. The possibility of capillary re-supply of water to the gel via the wick was investigated.

Evaporation and freezing were observed from the gel, as before, but no evidence of re-supply was observed.

3. Cermets and Sintered Powdered Metals as Water Moisture Release Regulators

Even if gels or gelling substances were satisfactory as moisture release regulators, a major, perhaps insuperable, drawback for their use lies in their material properties.

Gels do not have stable, durable shapes; they cannot be bonded or attached firmly in place; they foam and bubble under vacuum; they shrink, swell, and break; they must be handled carefully; they liquify above a minimum "setting" temperature; and, in general, they are extremely poor engineering materials.

The concept arose that the desirable properties regarding slow-release of water vapor might instead be accomplished by other, more controllable, engineering materials, and, in this connection, porous cermets and sintered powdered metals were investigated.

Porous Cermets can be fabricated with porosities which depend upon the ingredients and the cold, compacting process. Cermets of the appropriate porosity should have desired area flow characteristics for the in situ application. The electrical characteristics of a cermet enable it to be heated directly by passing a current through it. This is an important advantage which could be used to insure that

a specific porous area will remain open and not become covered with frost or ice during evaporation.

Sintered Powdered Metals can be manufactured in any size, shape, and porosity. Essentially, close tolerance porosity can be achieved by partial sintering of the powdered metal during the compaction process. As in the application of cermets, the metal can be heated directly to maintain porosity.

Porous structures manufactured from a variety of powdered metals have been developed. Battelle Memorial Institute at Columbus, Ohio, proved to be one of our best sources of information on these matters. Mr. Donald E. Kizer, Chief of the Powder Materials Applications Division, discussed with us some of the features of cermets and sintered powdered materials. Cermets as porous materials have not been studied extensively. They do exhibit various degrees of porosity, but the porosity has been observed only as a side property of the material, primarily in the manufacture of bearings. Little is known about reproducibility and ranges of porosity attainable. It is not anticipated that determining these properties would be a major hurdle if a program were instituted for this purpose. On the other hand, porosity ranges, reproducibility, and fabrication techniques for sintered powdered metals have been extensively investigated, and a great deal of information is currently available.

The following excerpts from a communication to us from

BIOSPHERICS INCORPORATED

Mr. Kizer at Battelle are reproduced here with his permission:

"....Some of the materials we have worked with include tungsten, molybdenum, tantalum, niobium, stainless steel, copper, nickel, beryllium, and several metal alloys.

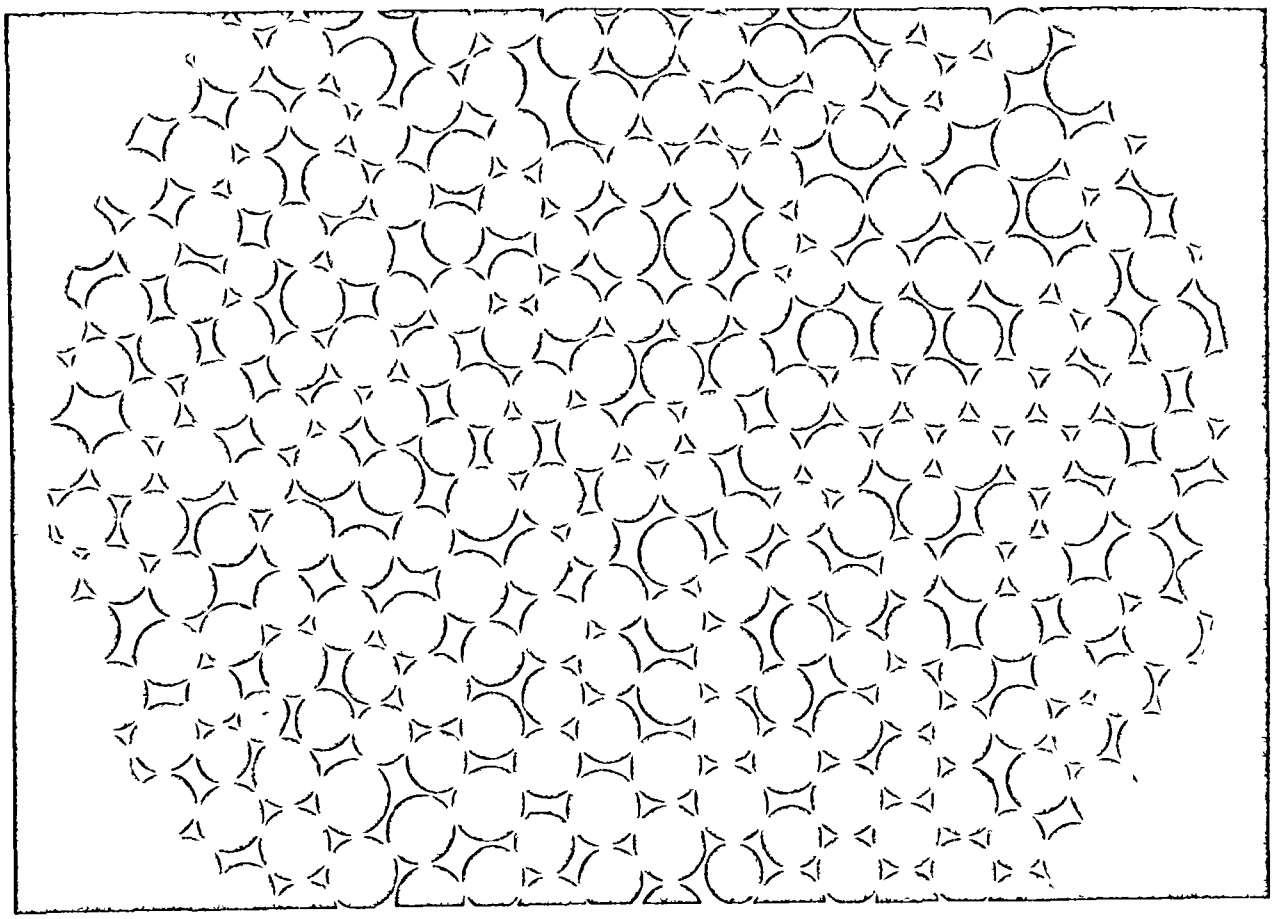
For many reentry applications, we have been involved in preparing and characterizing porous structures which required extreme control over the permeability. In many cases, use of commercially available spherical powders proved unsatisfactory to give the required control because of irregularities in the powder surface and shape. An example of some of the spheroidized material can be seen in the macro-view of as-spheroidized powder (shown in Figure 37). You will note that the sphericity of the powder is extremely uniform. By carefully sizing this material, one can fill a container to a very exact density. By compacting the material under carefully controlled pressures and temperature, a uniform structure is produced whereby the voids are geometrically distributed throghout the structure. By this technique, porous structures have been made to controlled densities utilizing powder of 50, 100, and 170 microns in diameter. The measured relationship of density powder size and permeability is shown (Figure 38). It will be noted that the same permeability in Darcy units can be obtained at different densities by adjusting the spherical powder size. The Darcy Equation is:

$$K = \frac{Q u l}{\Delta_p A}$$

Where:

K - is the permeability
Q - is the flow rate
u - is the fluid viscosity
Δ_p - is the pressure differential across the body
A - is the specimen cross-sectional area
l - is the specimen length

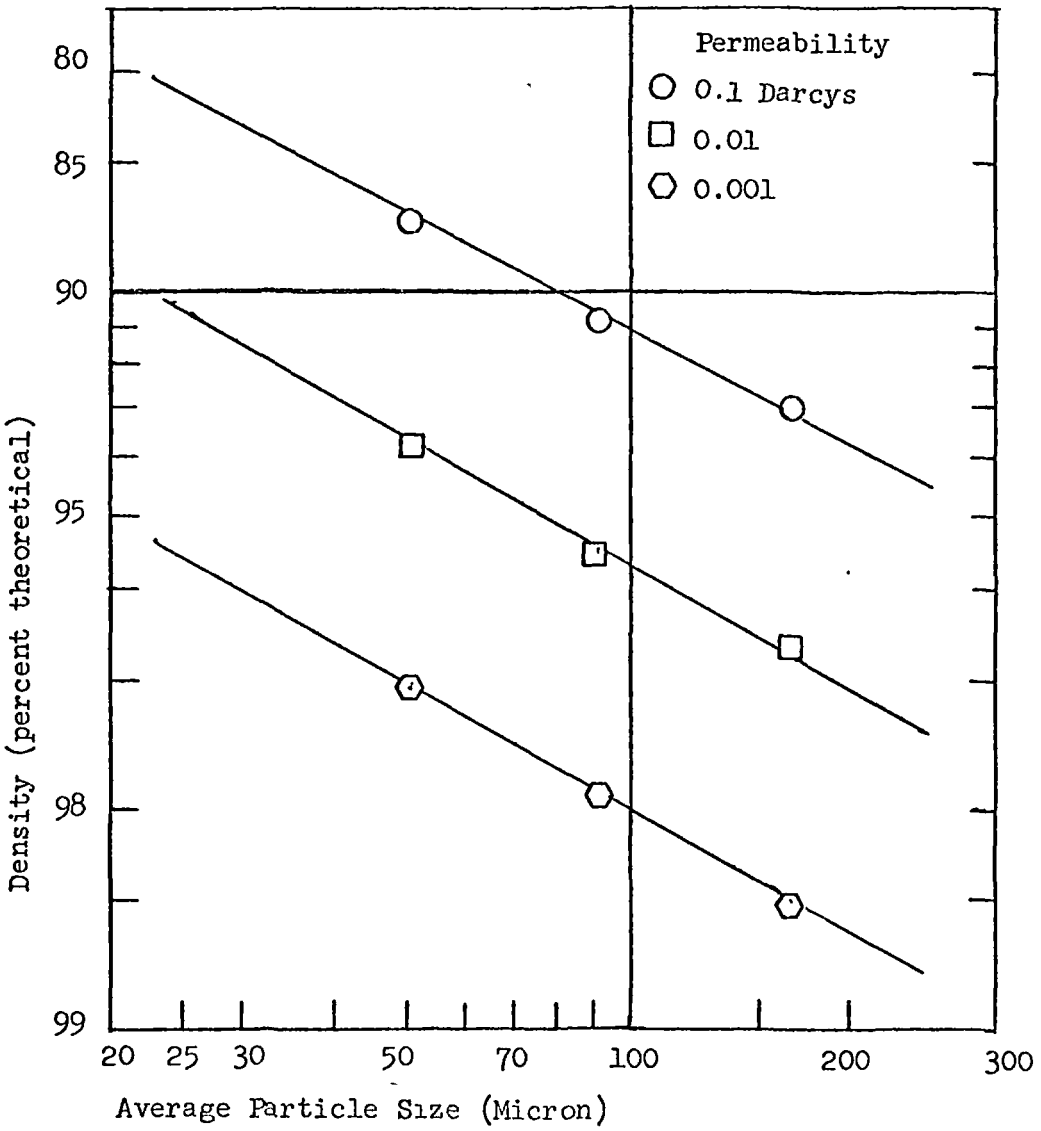
In order to reproduce the permeability to within $\pm$ 10 percent over the range shown (Figure 38), we have shown that



Plasma-Spheroidized Beryllium Powder

Particle is 149 to 177 micron (80 to 100 mesh). (50X)
Battelle Memorial Institute. By Permission.

	Fig 37		
BIOSPHERICS INCORPORATED			
Rockville Maryland	12-69 Date	Init.	Scale
NAS2-5360	In Situ Life Detection on Mars		



THE GRAPHICAL REPRESENTATION OF DENSITY CHANGE WITH MEAN PARTICLE SIZE AT CONSTANT PERMEABILITY LEVELS

Battelle Memorial Institute. By Permission.

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 38		
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the bulk density must be controlled to within ± 0.1 percent. Thus, you can see the necessity for the close control over the powder geometry and size for this particular requirement."

Unfortunately, the time and funds of the program did not permit laboratory experimentation with these materials.

4. Soil Sealants

Preliminary experimental investigations were conducted to study the behavior of substances which might be used as sealants to decrease the permeability of the soil. These investigations were aimed at determining the feasibility of injecting a substance into the Mars model soil which would make the soil impervious to water vapor or liquid losses.

Several substances were examined to determine their suitability to form a seal in the soil. As opposed to elastic gels considered earlier in the program because of their properties to imbibe and retain water, inelastic gels were considered here because of their property not to imbibe water after drying. Other materials ranged from molten paraffin to paraffin in various solvents to collodion.

4.1 Silica Gel

Silica gel, an inelastic gel, was prepared using sodium silicate and phosphoric acid. After preparation, some of the gel was placed in the Martian simulation chamber and allowed to dry under vacuum. The rest of the gel was placed

in an oven and allowed to dry at 140° F at ambient pressure.

Results:

a. The silica gel in the Mars environmental chamber frosted over and froze before drying. It became dry after several hours of exposure to the low atmospheric pressure.

b. The silica gel in the drying oven dried in a short time.

c. Both silica gels dried up to a powder which did not regenerate to a gel upon addition of water. However, the powdery, chalky material does not offer any sealing characteristics, and hence, cannot be used for this application.

4.2 Molten Paraffin

Molten paraffin was introduced into the Mars environmental chamber and subjected to the reduced atmospheric pressure

Results:

The paraffin boiled at the reduced atmospheric pressure. Because of the high heat capacity of the material, the paraffin remained warm and molten after 20 minutes. Solidification is extremely slow under vacuum. The slowness of the process does not lead to a suitable solution.

4.3 Dissolved Paraffin

To maintain paraffin fluid at a low temperature without melting, the paraffin was dissolved both in hexane and in chloroform, and each solution was put in the Mars environmental chamber.

Results:

At the reduced pressure, the temperature of the solvents was high enough for the solvents to start boiling off. After a few minutes, the samples were removed and examined. The texture of the deposited wax was pasty and of a snowy appearance. At a temperature below the boiling point of the solvent at 6 torr, the wax may have deposited out with a different. However, the important result here is that as the solvent evaporates and the wax solidifies, the dissolved wax tends to encapsulate itself by forming a scab-like outer surface which retards evaporation of the solvent and maintains a pasty core. Therefore, this approach does not lead to a solution.

4.4 Collodion - (I)

Collodion was introduced at room temperature (approximately 30° C) into the Mars environmental chamber, both in a small beaker and in a petri dish.

Results:

a. Under the reduced pressure, the collodion solvents evaporated (boiled) very rapidly. Within a few minutes, the solid material was left behind in a sheet-like piece of transparent film material.

b. Immersion of the transparent sheet in water for several days showed no indication of absorbing water or softening.

c. A piece of the transparent film was clamped between two flanged tubes to determine if the film were impervious. To this effect, the tubes were placed in a vertical position, water was put in the top section above the approximately 2-ml thick collodion film. The film did not show permeability or porosity to water during a two-day period of observation.

4.4 Collodion - (II)

A one-inch diameter plastic tube open at both ends was covered at one end with a sheet of filter paper held

in place by draping it around the tube and clamping it with rubber bands.

One tube was then filled to within one-quarter of its length with dry Martian model soil. While the tube was in a vertical position, collodion was injected at the top surface by means of a large-bore hypodermic needle. Injection was about one inch below the surface. Sufficient collodion was injected until there was visual evidence through the plastic tube that chances for a complete seal formation of the soil column were good. The tube was then placed in the Mars environmental chamber and exposed to low pressure and CO_2 atmosphere for approximately 15 minutes.

Results:

The tube was taken out of the chamber and held in a vertical position. Water was added to the plastic tube over and above the soil column, and the whole thing allowed to sit at room ambient conditions for 24 hours. The seal did not allow water to penetrate. Nor did seepage occur when the water pressure was increased by raising the water level to approximately one-half inch above the soil surface. and the tube allowed to sit for an additional 8 hours.

4.5 Discussion

It would appear that if a substance such as collodion is injected into the soil and poured around an in situ de-

vice, a seal could be effected which would greatly reduce or eliminate the loss of water vapor. It would allow the existence of a moist environment with water and water vapor in equilibrium within the resulting "closed" environmental volume in the soil-in situ device. Atmospheric gas exchanges and admittance of light could be maintained through the use of gas semi-permeable membranes and transparent enclosures in the same manner as if the sealant were the ice barrier. The water supply necessary under these conditions would obviously by only a small fraction of that required for the same experiment and duration when ice seals are considered.

At the concentration used in this experiment, the collodion viscosity was somewhat high. It is anticipated, however, than thinning to any desired lower viscosity would not present any problems. Lowering of the temperature would result in a less vigorous evaporation or ebullition during injection.

Since it is important to prevent contamination of the experiment with organic vapors, it is envisioned that one possible mode to implement the sealing action for an in situ device, should a substance such as collodion be used, would be as follows:

After a predetermined amount of time and after sufficient injection of water to insure formation of a "primary" ice seal, a second "layer" encapsulation over the ice seal could be effected by means of

a thin solution of a collodion-like substance.

The initial encapsulation with ice would isolate the experimental volume in the manner already described in order to prevent or greatly reduce contamination from the solvent vapors. The second (collodion) encapsulation would prevent or drastically reduce continued loss of water through sublimation Moisture sensors would initiate addition of water (liquid or vapor) as required for the desired moisture level within the experimental volume. Additional water would be added depending on other water losses caused deliberately by atmospheric gas exchange through membranes or by controlled period venting to the atmosphere.

5. Worst Case Water Loss for an Ice Barrier

In order to estimate the water loss and energy supply requirements to maintain an ice barrier for isolation of an in situ experimental volume, an analysis of an upper limit for water loss from an ice barrier was performed. The following assumptions were made:

a. A closed experimental volume is isolated by an ice barrier with an exposed surface area of 40 cm^2.

b. The initial ice-barrier thickness is 1 cm and is maintained at 1 cm by a supply of water.

c. Evaporation or sublimation from the ice is into a 4π infinite sink with molecules leaving the ice surface and being permanently lost to the surface.

d. The number of molecules leaving the surface per second is given by:

$$N_L = \frac{N_F}{\alpha_F \sqrt{\pi}} \int_S^\infty U \exp\left(\frac{-U^2}{\alpha_F^2}\right) dU$$

$$N_L = \frac{N_F \alpha_F}{2\sqrt{\pi}} \exp\left(\frac{-S^2}{\alpha_F^2}\right)$$

Where:

N_F represents the number of molecules in 1 cc

α_F = the most probable speed of molecules

S = the escape velocity of water molecules crossing the interface from the liquid to the gas phase

U = the velocity component of the molecules along an axis normal to the top surface

e. Temperature inside the volume is at 20° C, and maintained by a supply of water and a heat source.

f. Temperature outside the ice barrier is given by a hypothetical "probe" at the outside of the barrier following variations in outer environmental temperature.

The analysis represents a worst case in the sense that all molecules leaving the surface are lost. This represents an upper limit, where evaporation is into a sink of infinite pumping speed. The lower limit, of course, is at equilibrium conditions where the number of molecules leaving is equal to the number of molecules returning, and there is no net loss.

Results of the calculations are shown in Figures 39, 40, and 41.

4.2-C Moisture Application Approaches

Application of moisture to the experimental in situ volumes includes wetting of the soil sample. Water can be introduced into the volume as a vapor, a liquid, or a solid. Both solid and vapor phases contribute only vapor to the immediate experiment volume through sublimation of the ice and release of vapor by the vapor source. Under the anticipated low moisture content and the low pressure of the Martian atmosphere, liquid water is not expected to exist for appreciable periods of time on the surface of Mars.

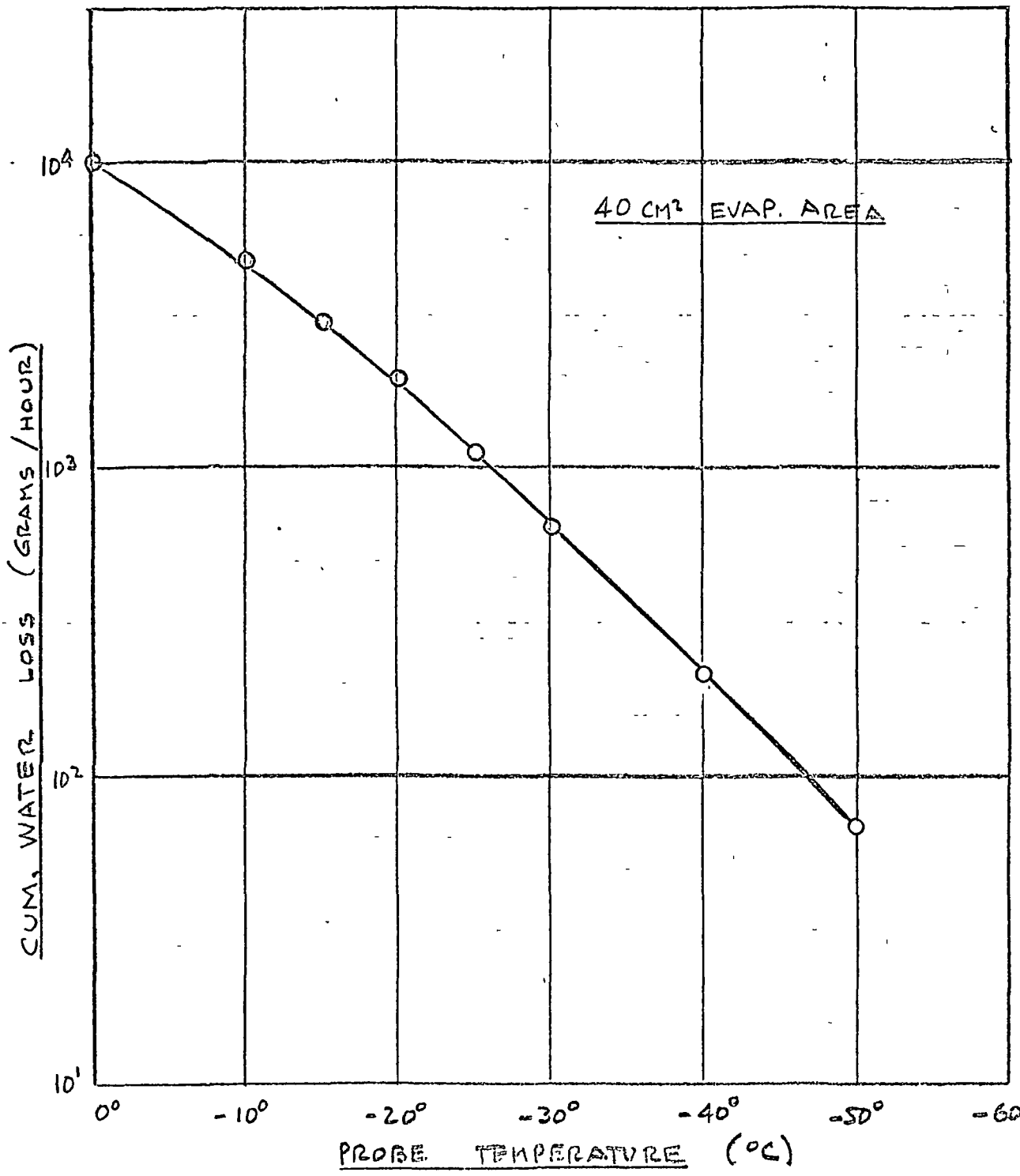
The introduction of water vapor alone by any means will not accomplish wetting of the soil. The soil and the experimental volume will not be "wet" unless condensation occurs because of super-saturation. Introduction of liquid water can accomplish three basic functions:

a. seal the experimental volume in the sub-soil leakage area by creating an ice-soil seal,
b. wet the soil sample area within the sealed experiment volume, and

PROBE TEMP. °K	VAPOR PRESS. OF WATER AT PROBE TEMP. TORR	MAX. WATER VAPOR LOSS THROUGH 40 CM² SFCE AREA. GMS/HR	HEAT OF SUBLIMATION (675.6 CAL/g) TO VOLATILIZE ICE K-CAL/HR	TEMPERATURE DIFF. ACROSS ICE BARRIER °C	HEAT SUPPLIED TO INTERIOR OF SYSTEM BY 20°C WTR PLUS HEAT OF FUSION K-CAL/HR	HEAT TO BE ADDED TO SYSTEM FOR EQUIL. CONDITIONS. K-CAL/HR	AVAILABLE HEAT TRANSFER ACROSS ICE BARRIER K-CAL/HR
293	17.535			+20			
288	12.788			+15			
283	9.209			+10			
278	6.543			+ 5			
283	4.579	10,232.	6,917	0	1,022	5,895	0.
268	3.013	6.796.	4,594	- 5	679	3,915	4.1
263	1.950	4,439	3,001	-10	442	2,559	8.2
258	1.241	2,852.	1,928	-15	284.	1,644	12.3
253	0.766	1,801.	1,217	-20	179	1,038	16.4
248	0.476	1,116	754	-25	111.	643	20.5
243	0.286	677.	458	-30	67.6	390	24.6
238	0.1681	402	272	-35	40.1	232	28.7
233	0.0966	234.	158	-40	23.3	135	32.8
228	0.0541	132	89	-45	13.2	76	36.9
223	0.0296	73	49	-50	7.3	42	41.0

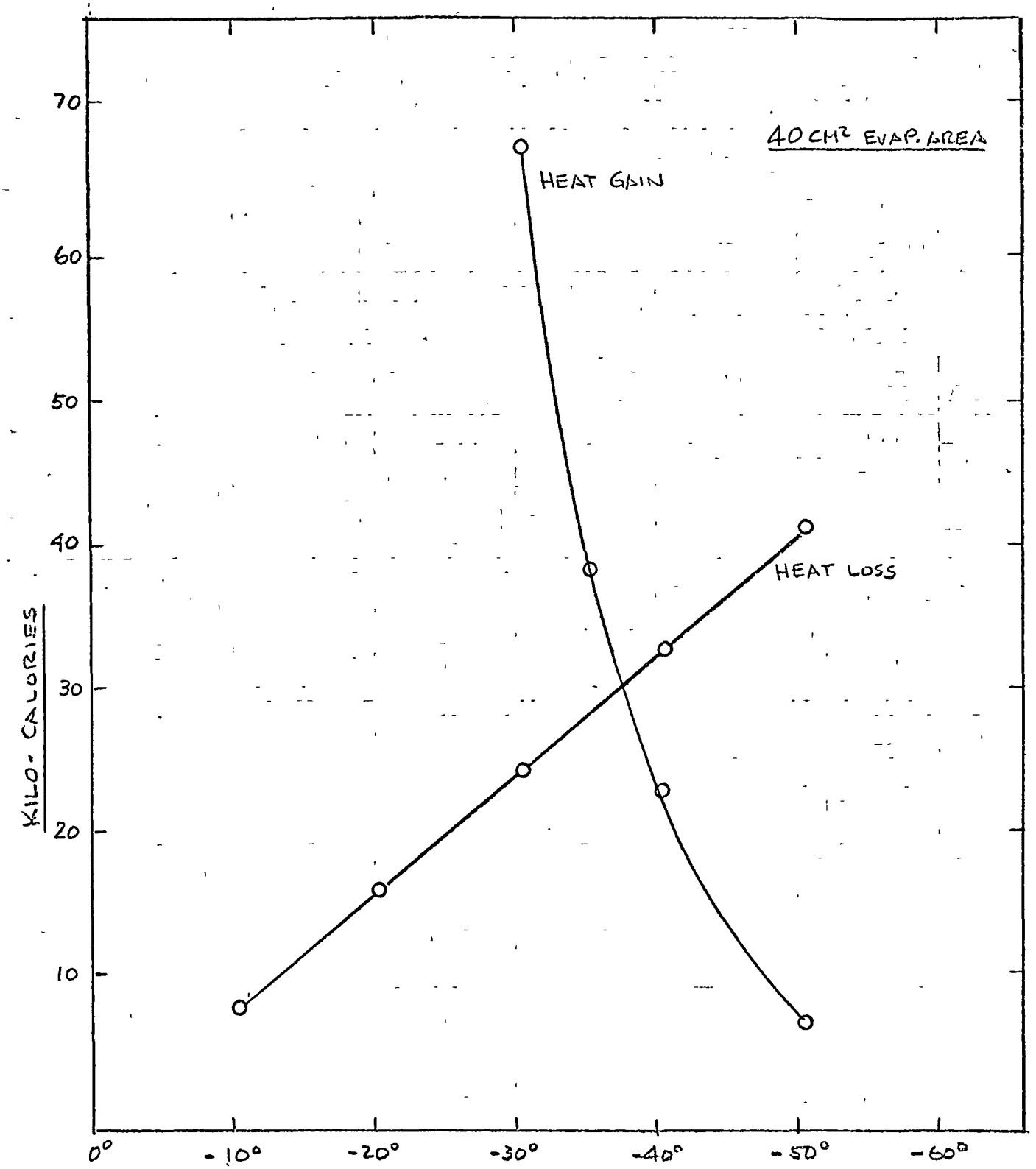
Table of Thermodynamic Analysis of
In Situ Model Ice Barrier
WORST CASE CALCULATIONS.

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 39	
	12-69 Date	Init / Scale
NAS2-5360 Cont. No	In Situ Life Detection on Mars Report Title	



WATER LOSS THROUGH EVAPORATION (WORST CASE) VS. OUTSIDE TEMPERATURE AT PROBE.

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 40			
	12-69 Date	Init	Scale	
NAS2-5360 Cont. No.	In Situ Life Detection on Mars Proj. Title			



THERMAL BALANCE. (WORST CASE)

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 41		
	12-69 Date	Init	Scale
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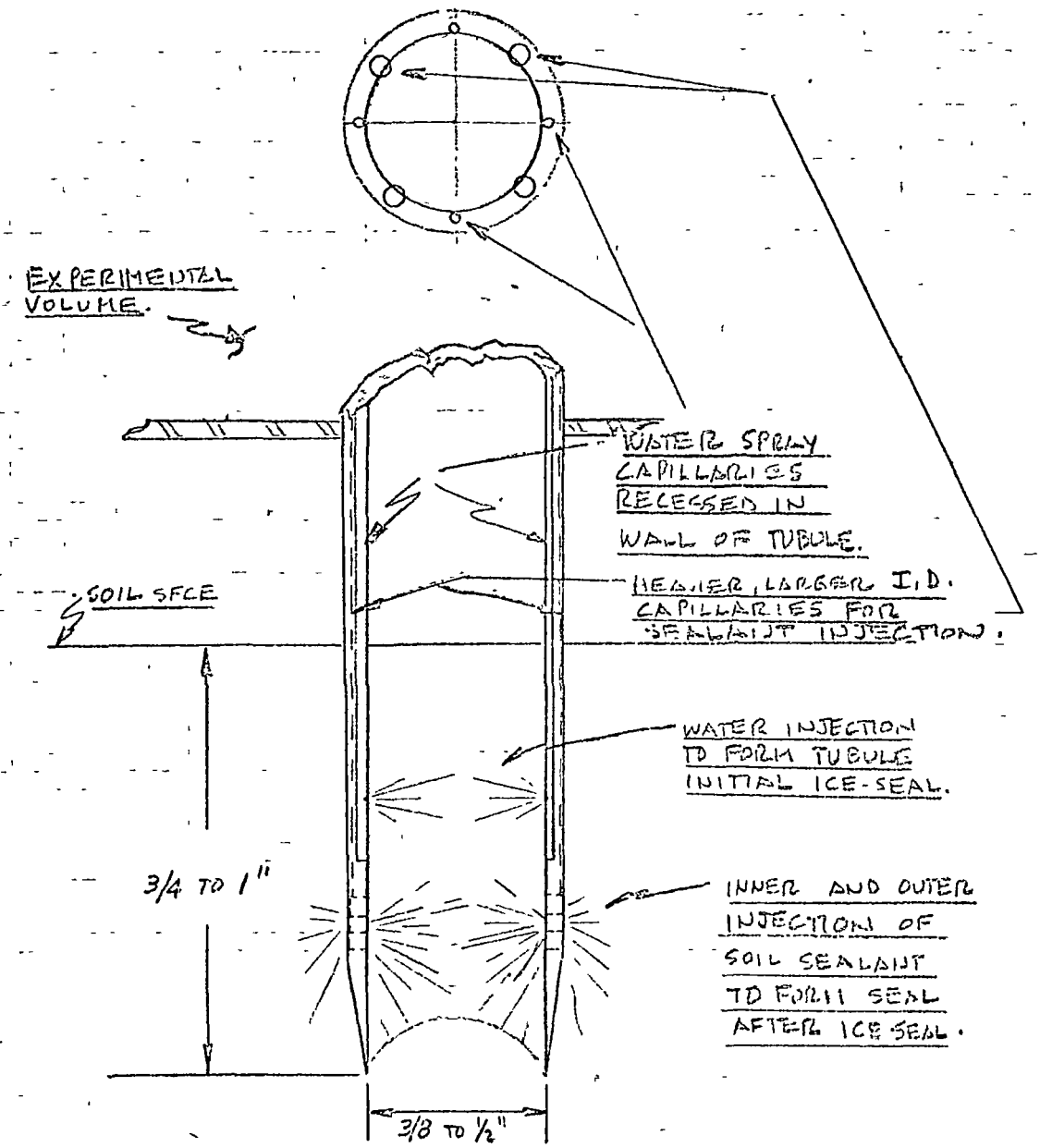
c. supply moisture in the form of saturated vapor to the enclosed experiment volume by (either or both) evaporation or sublimation.

Based on these considerations, an evaluation of capillary applicators for direct introduction of liquid water to the soil sample was initiated. Single and multicapillary applicators were investigated. Preliminary analysis of the capillary led to the concept of a multi-tube in situ device as opposed to a capillary applicator device. A multi-tube arrangement affords redundancy and allows smaller and more efficient seals for each tube. In addition, some of the inherent drawbacks of a multicapillary arrangement are avoided.

The tube concept would utilize capillaries, but they would be built into the wall of the tube to spray out water to seal the bottom of the tube after soil penetration prior to injection of a sealant below the ice plug. A schematic of the tube concept is shown in Figure 42.

The sealing procedure would be designed and initiated in such a manner that all tubes would be sealed whether they penetrate the soil or not. Introduction of moisture into the experimental volume would follow until saturation was reached.

Because the single capillary applicator demonstrates these principles and offers the simplest experimental approach to study the



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TUBULE - MULTI-TUBE DEVICE FOR "IN-SITU" EXPERIMENT. SCHEMATIC OF CROSS-SECTION (TOP), AND VERTICAL SECTION (BELOW).

BIOSPHERICS INCORPORATED Rockville Maryland	Fig 42		
	12-69 Date	Init	Scale
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effectiveness of creating an ice barrier and a moist environment in the soil under simulated Martian conditions, it was selected for continued study in the balance of the program.

4.3 Single Capillary Applicator

4.3-A Experimental Work

1. Introduction

Having selected the single capillary applicator as the simplest and most effective method of moisture application to the soil, an experimental technique was developed to determine its operating characteristics under simulated Martian conditions. Both the transient ice-barrier formation process and the long-range, dynamic behavior of the barrier-applicator were studied.

The temperature profile of the resultant moistened soil volume was continuously sampled automatically and recorded on a strip chart recorder.

The information obtained allowed determination of the fact that an ice barrier indeed does form upon injection of water into the soil, and a moist (not-iced) core is maintained for several hours in the absence of control adjustments. Injection flow often stops after several hours after the ice barrier is formed because of freeze-up of the initially moist core. Small environmental temperature adjustments on the ice barrier temperature profile furnished by the thermistor sensors allowed a moist core to be maintained much longer.

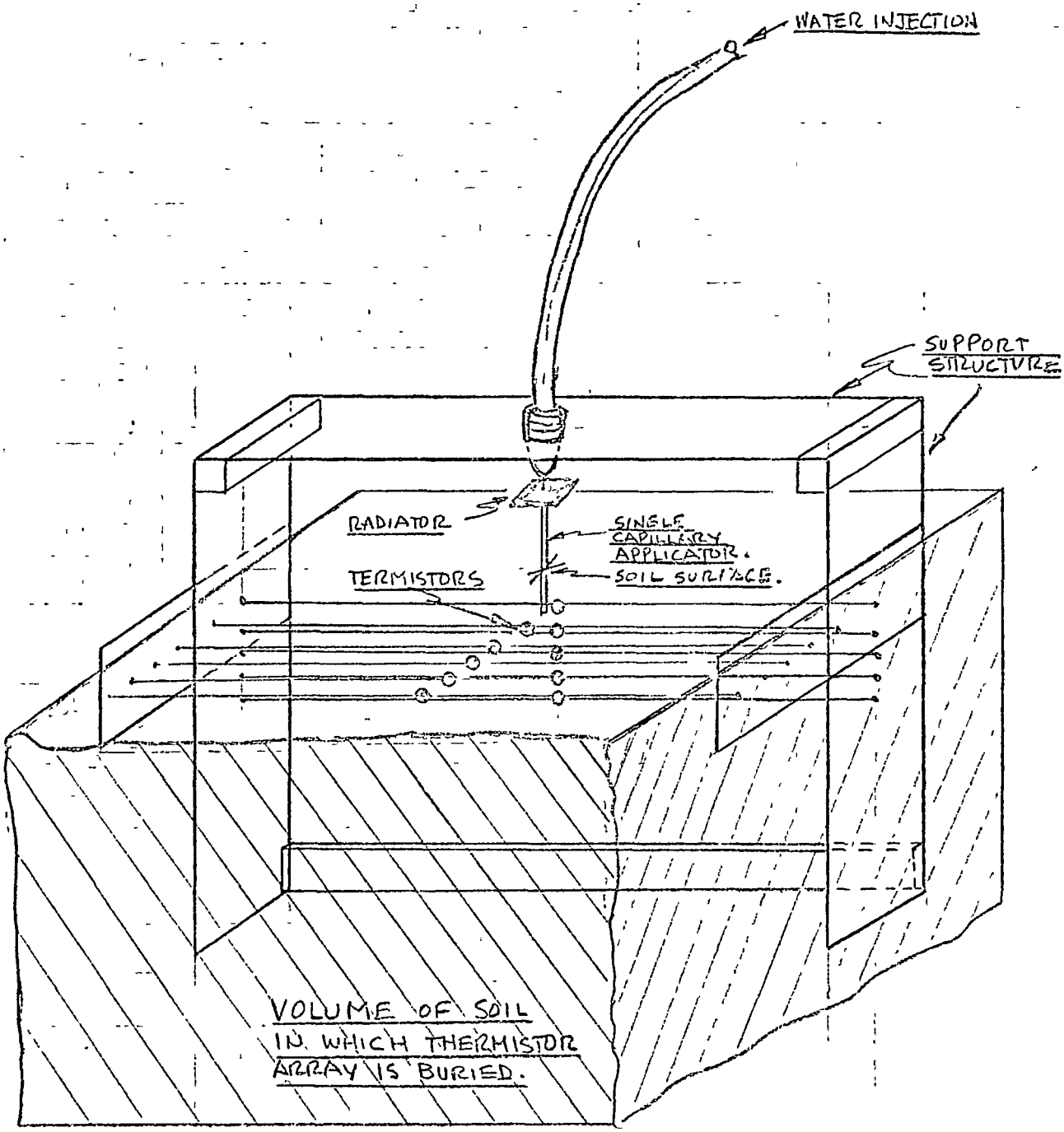
A flow re-initiation process was successfully demonstrated several times. The long-range dynamic studies led to the determination that the ice barrier could be controlled to remain in an ice barrier-moist center configuration indefinitely.

2. Experimental Apparatus

The experimental apparatus was based on the utilization of precision thermistors as temperature probes implanted in the soil. Thermistor probes were placed in a vertical arrangement of five and a horizontal arrangement of five for a total of ten. Figure 43 and Figure 44 show the probes' arrangement and dimensions.

Figure 45 shows the electrical circuit schematic for automatic probe sampling and recording. Essentially, it consists of an adjustable time motor which actuates a microswitch at a time interval selected from a range of from two seconds to one minute and energizes an impulse latch relay while at the same time recycles the timer. The latch relay drives a wiper which samples the output of each thermistor and sends the information to a Keithley Model 610C electrometer which is used as a resistance bridge. The Keithley electrometer in turn feeds the temperature data in terms of resistance to a strip-chart recorder.

The probes are sampled from the outside toward the center of the radial arrangements. Two external precision 1% thin film re-



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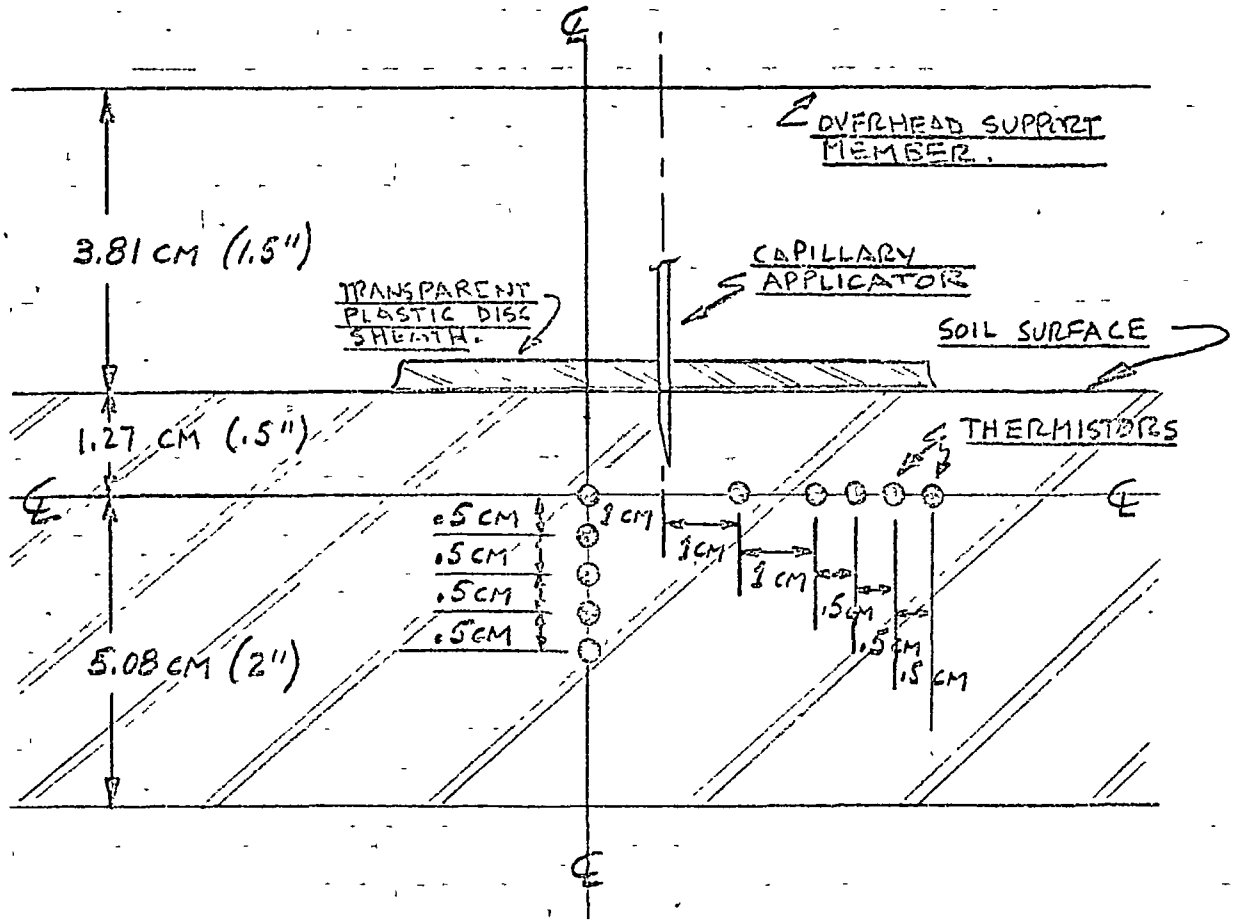
ICE BARRIER TEMPERATURE PROFILE DETERMINATION.
THERMISTOR PROBES ARRAY.
ARRANGEMENT AND LOCATION.

BIOPHYSICS INCORPORATED, Rockville Maryland	Fig 43		
	12-69 Date	Init.	Scale
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		

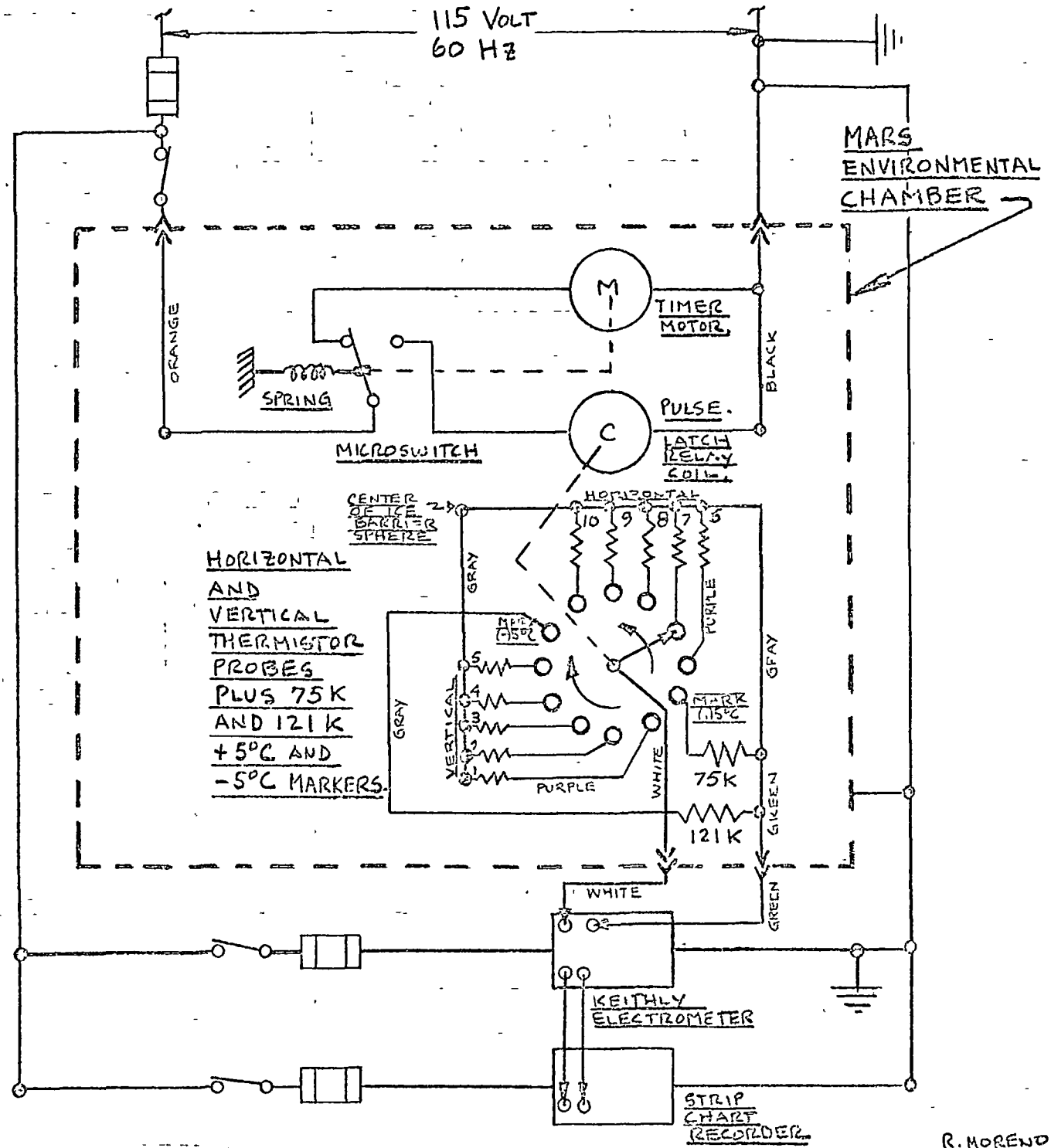


(RELATIVE DISTANCES TO SCALE.

R. MORENO

ICE BARRIER TEMPERATURE PROFILE DETERMINATION.
THERMISTOR PROBES ARRAY.
DIMENSIONS.

BIO-MEDICS INCORPORATED, Rockville Maryland	Fig 44		
	12-69 Date	Rev.	Scale
NAS2-5360	In Situ Life Detection on Mars		



R. MORENO

ICE BARRIER TEMPERATURE PROFILE DETERMINATION. TEST CIRCUIT SCHEMATIC.

BIOSPHERICS INCORPORATED, Rockville Maryland	Fig 45		
	12-69 Date	Init	Scale
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		

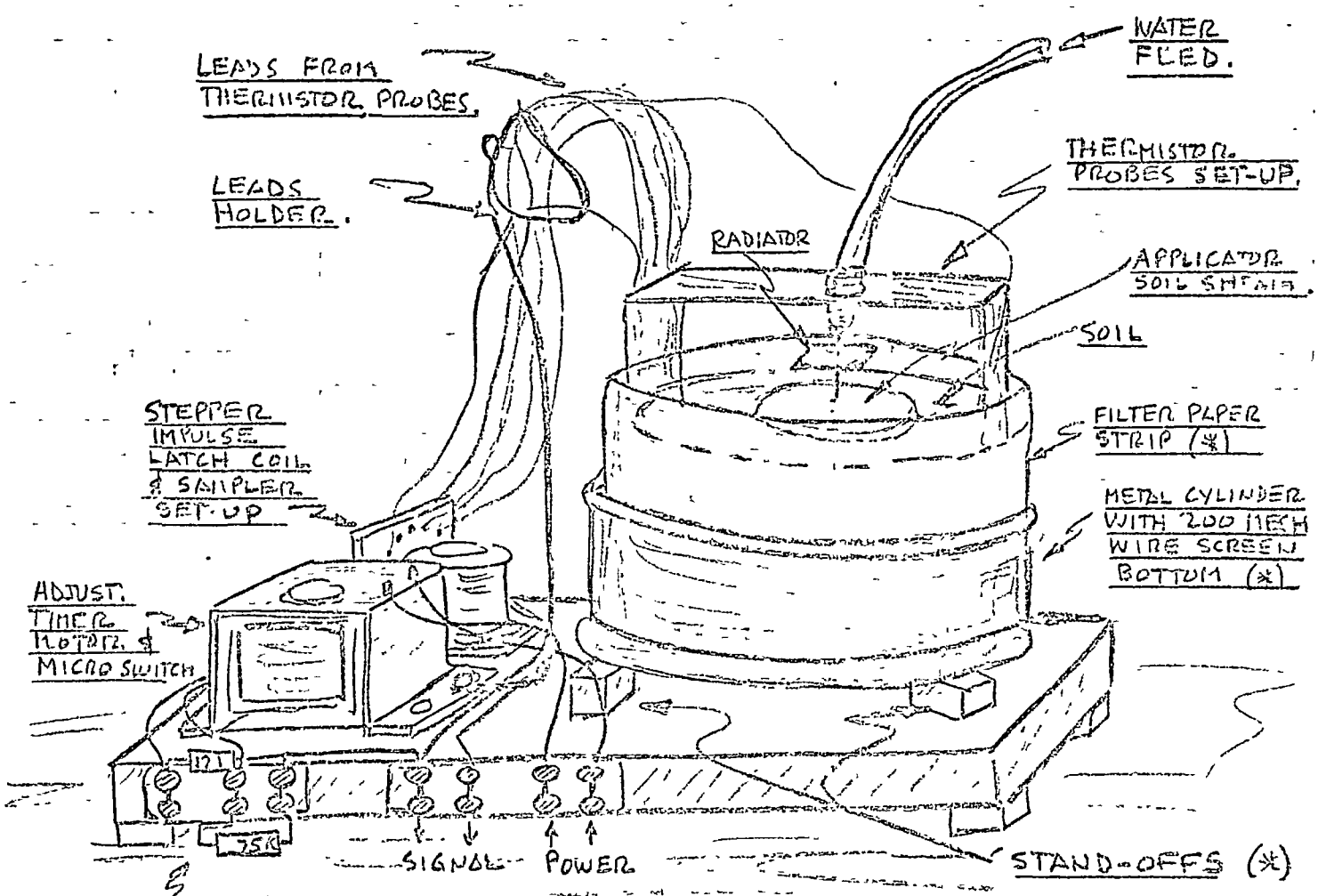
sistors are used as "markers" to differentiate between the two sets of probes and give an indication of which, the vertical or the horizontal set, as well as which of the probes in each set is being read. In addition to serving as "markers," the two resistors act as calibration points since they were selected so that their values would come as closely as possible to the equivalent resistance of thermistors indicating +5° C and -5° C. Figure 46 shows in sketch form the components and arrangements of the experimental test-assembly. Figure 47 is a block diagram of the complete test set-up.

In Figure 48 a section of the strip-chart record shows the temperature profile of a fully developed ice barrier with a moist center. The markings on the graph are self-explanatory.

3. Results

Water was injected using the single capillary applicator approach, and a transparent, plastic, disc-shaped "shroud" was used to cover the soil above the point of injection.

The experimental program led to the determination of the fact that a stable condition could be maintained indefinitely where a moist core was surrounded by an ice barrier in the soil. It was determined also as a result of the experimental program that the injection flow can be interrupted and re-started as often as required and that each time the ice barrier-moist center configuration can

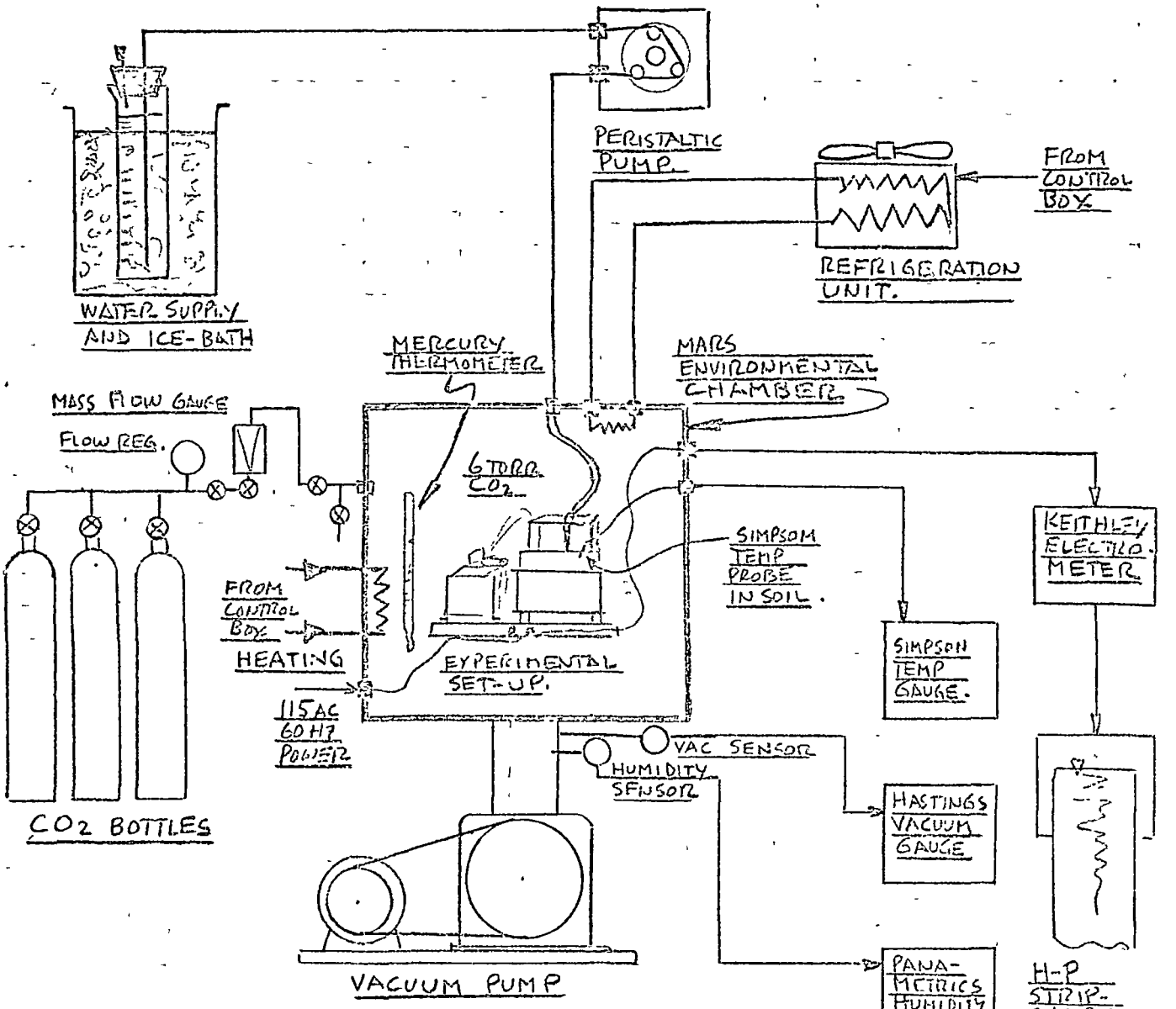


75K & 121K
1% THIN FILM RESISTORS
FOR (4)5°C AND (1)5°C MARKERS.

NOTE
(*) - TO ALLOW FREE OUTFLOW OF GAS AND VAPORS FROM SOIL DURING WATER INJECTION.

ICE BARRIER TEMPERATURE PROFILE DETERMINATION.
THERMISTOR PROBES ASSLY.
EXPERIMENTAL SET-UP. SKETCH OF LAY-OUT.

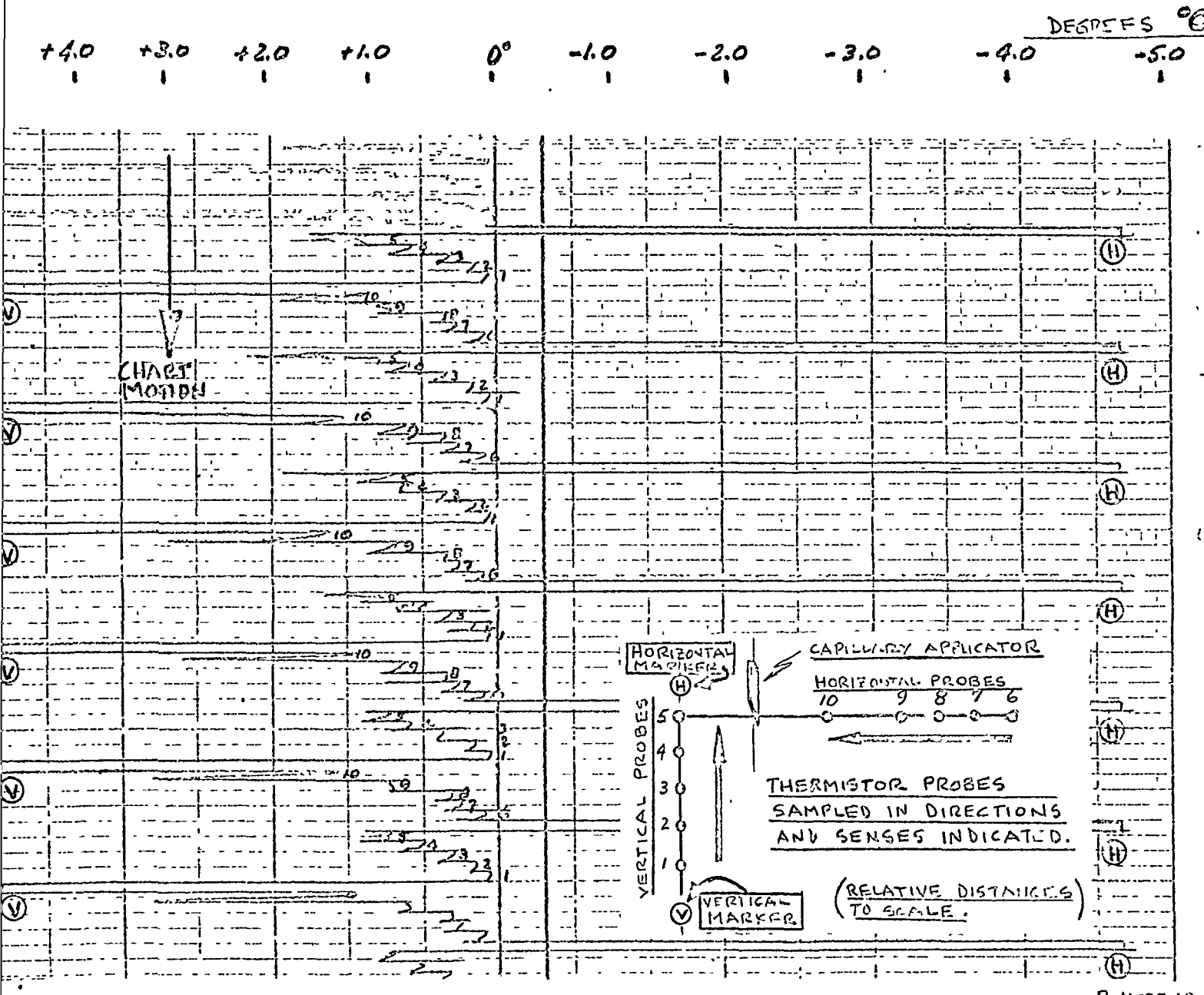
BIOSPHERICS INCORPORATED Rockville Maryland	Fig 46		
	Date 12-69	Inst.	Scale
NAS2-5360	In Situ Life Detection on Mars		



R. MORENO

ICE BARRIER TEMPERATURE PROFILE DETERMINATION.
TEST SET-UP & BLOCK DIAGRAM.

BIOSYSTEMICS INCORPORATED Rockville Maryland	Fig 47			
	12-69 Date	Init	Scale	
NAS2-5360	In Situ Life Detection			



ICE BARRIER TEMPERATURE PROFILE DETERMINATION. TYPICAL STRIP CHART RECORDING. SHOWN ABOVE A SECTION OF CHART AT STABLE CONDITION JUST PRIOR TO ICE BARRIER FORMATION WITH MOIST SOIL.

Fig	26
BI[illegible]ICS INCORPORATED	
Rockville, Maryland	12-69 (Date) / (Int) / (Scale)
NAS2-5360 (Cont No)	In Situ Life Detection on Mars (Report Title)

be brought to and maintained at stability as long as desired.

Temperature profiles of ice barrier-moist center configurations are shown in Figures 49 through 60 in the form of three-dimensional plots. Figures 49, 51, and 53 depict extreme conditions in which the experimental volume is either nearly completely frozen or thawed. The experimental volume of Figure 49 is almost completely frozen. The added water flows from the applicator, up to the top, and over to the outside of the "ice ball" which forms upon cessation of water flow to the experimental volume. Figure 55 shows a situation in which a moist center has been established, but the overall low temperatures indicate that the configuration is in danger of freezing solid if any significant reduction in heat imput would occur. Figure 57 and Figure 59 show configurations in a stable condition with an adequate margin for control to maintain the ice barrier and moist center.

4.4 Feasible In Situ Life Detection System

4.4-A Introduction

Several tests were conducted to determine the performance in an in situ life detection system under simulated Martian conditions after the problem of maintaining a moist environment under these conditions was solved. The tests included detection of biological response, getter efficiency, and overall system efficiency.

Temperature °C

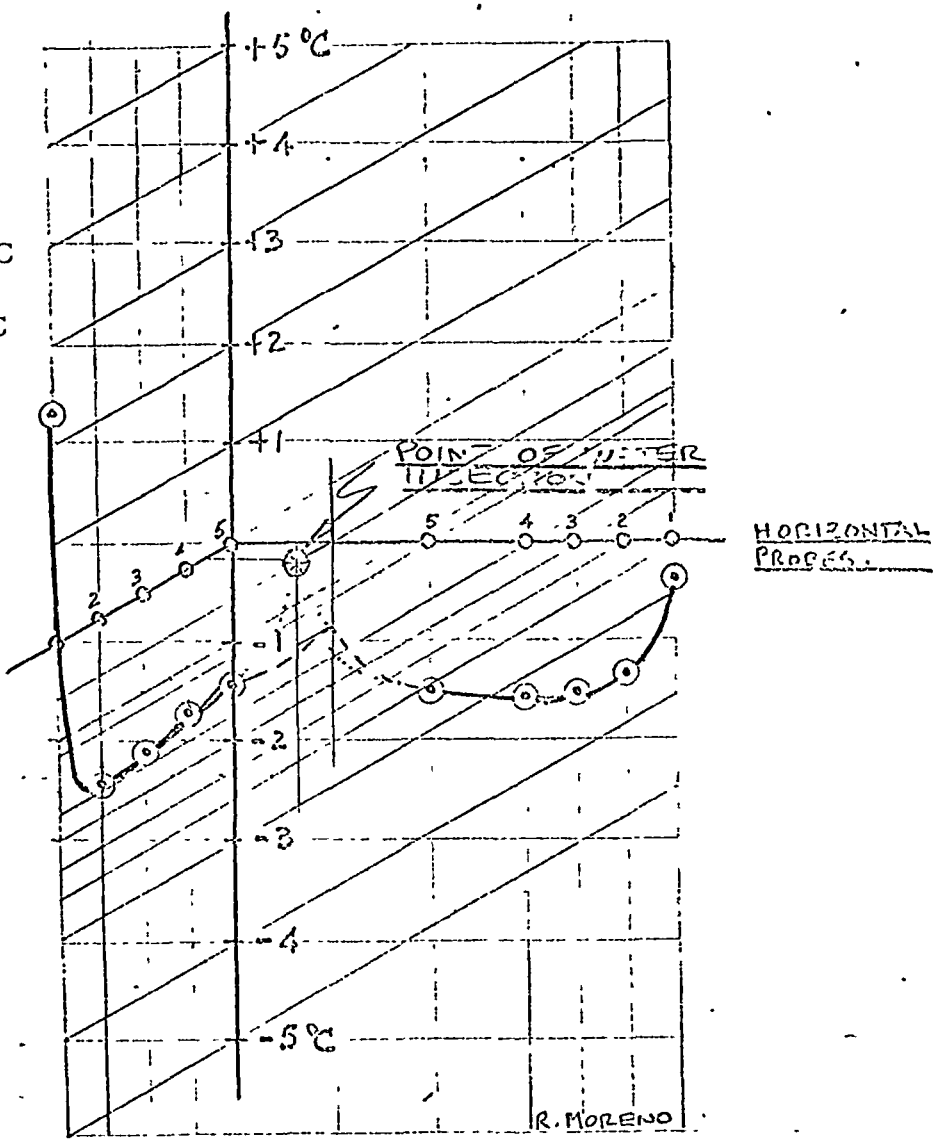
Pressure 6 torr

Atmosphere CO_2

Frost Point (-) 37°C

Soil Temp. (+) 30°C

Mars Box Wall Temp. (+) 36°C

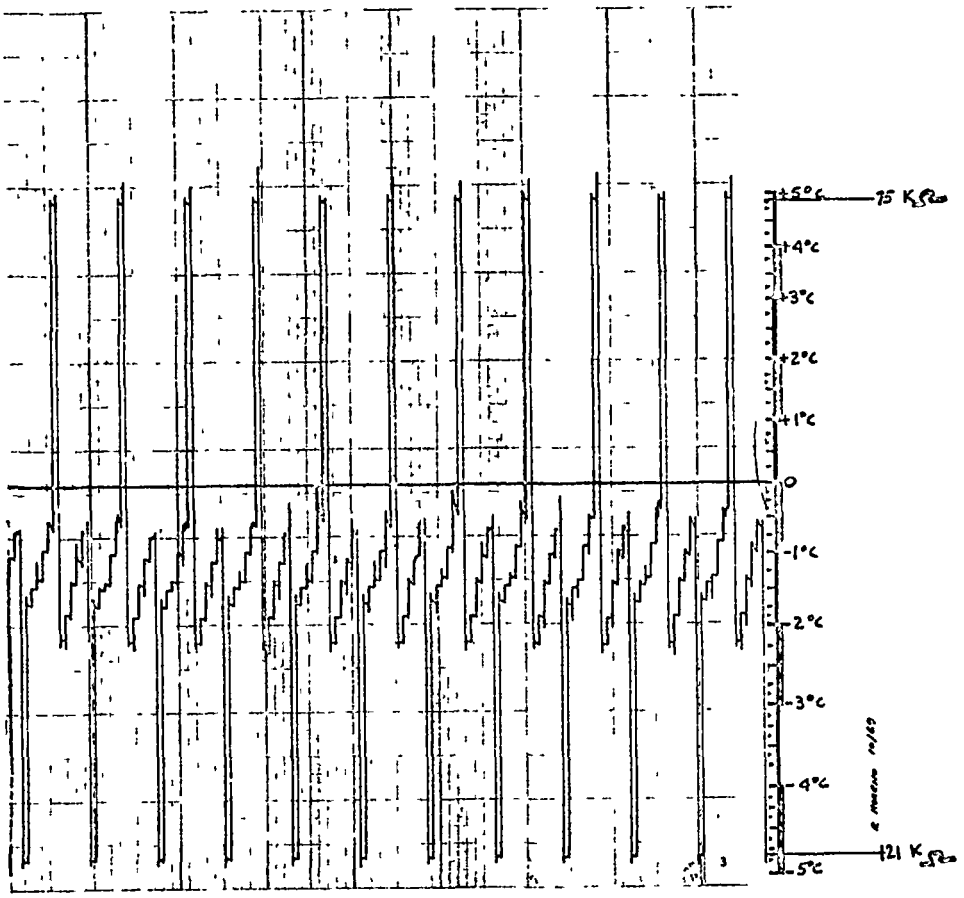


2 Research on Ice Barrier Moist Center Formation. Single Capillary Applicator

An extreme condition: almost complete freezing. Water injection still in progress but liquid spills out and over the top at the center of the ice "Ball". (Water Injection Rate: Approximately 5 ml/hr.)

Note: Dots (not dashes) indicate probable temperature profiles in the vicinity of the temperature axis through the point of water injection.

	Fig 49			
D'	ICS INCORPORATED			
Rockville Maryland	12-69 Date	Init	Scale	
N 62-53[illegible] Cont No	In Situ Life Detection on Mars Report Title			



Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 49

	Fig 50		
BI[illegible]ICS INCORPORATED			
Rockville Maryland	12-69 Date	Init	State
NAS2-5360 Contract No.	In Situ Life Detection on Mars Report Title		

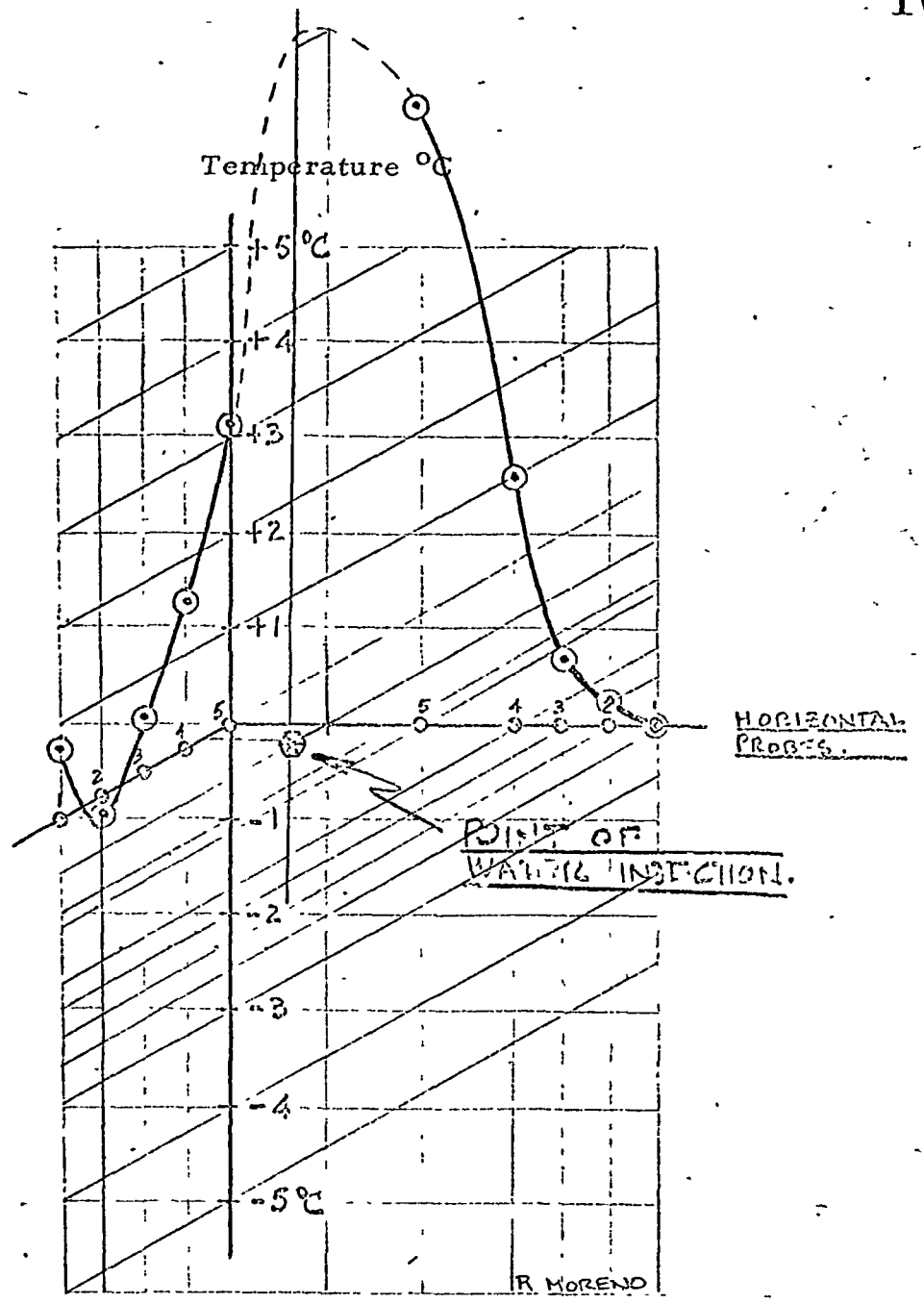
Pressure 6 torr

Atmosphere CO_2

Frost Point (-) 36°C

Soil Temp. (=) 35°C

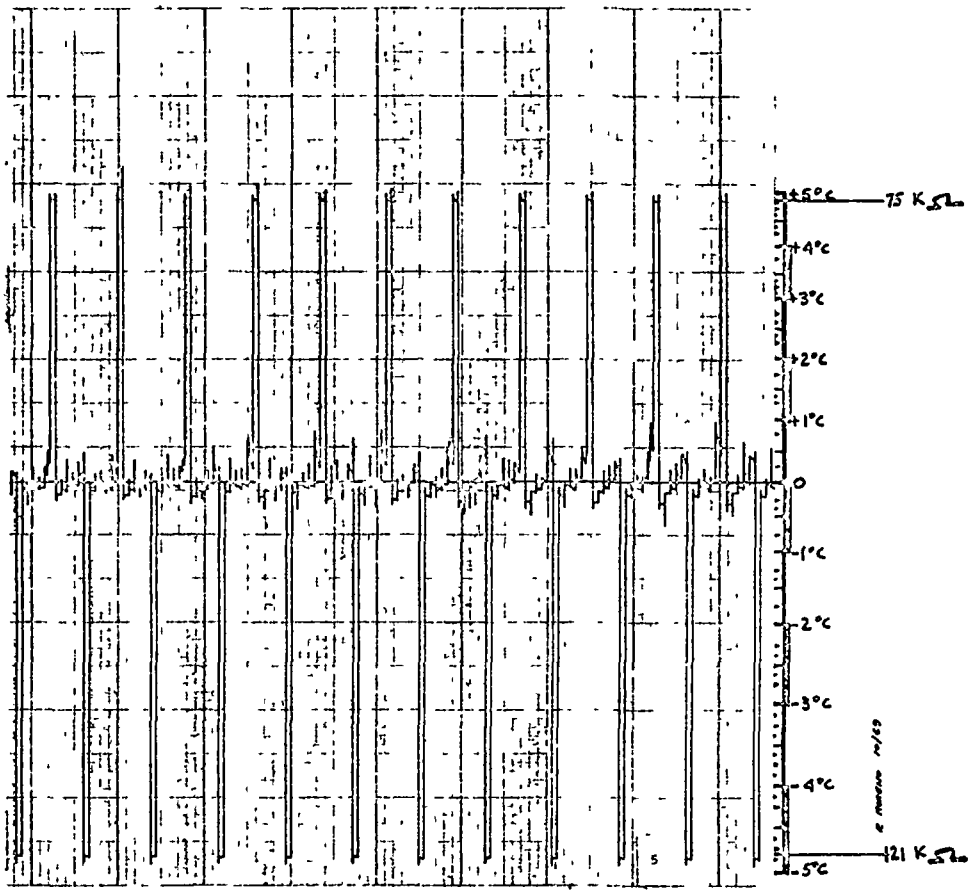
Mars Box Wall Temp. (+) 45°C



Research on Ice Barrier Moist Center Formation. Single Capillary Applicator

An extreme condition: almost complete thaw-out. Water injection in progress. Moist warm core but ice barrier nearly non-existant. (Water Injection Rate: Approximately 5 ml/hr)

	Fig 51			
DI	ICS INCORPORATED			
Rockville Maryland	Date 12-69	Init	State	
NAS2-5360	In Situ Life Detection on Mars			



Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 51

	Fig 52	
ICS INCORPORATED		
Rockville Maryland	12-69 Date	Init / Scale
NAS2-5360	In Situ Life Detection on Mars	

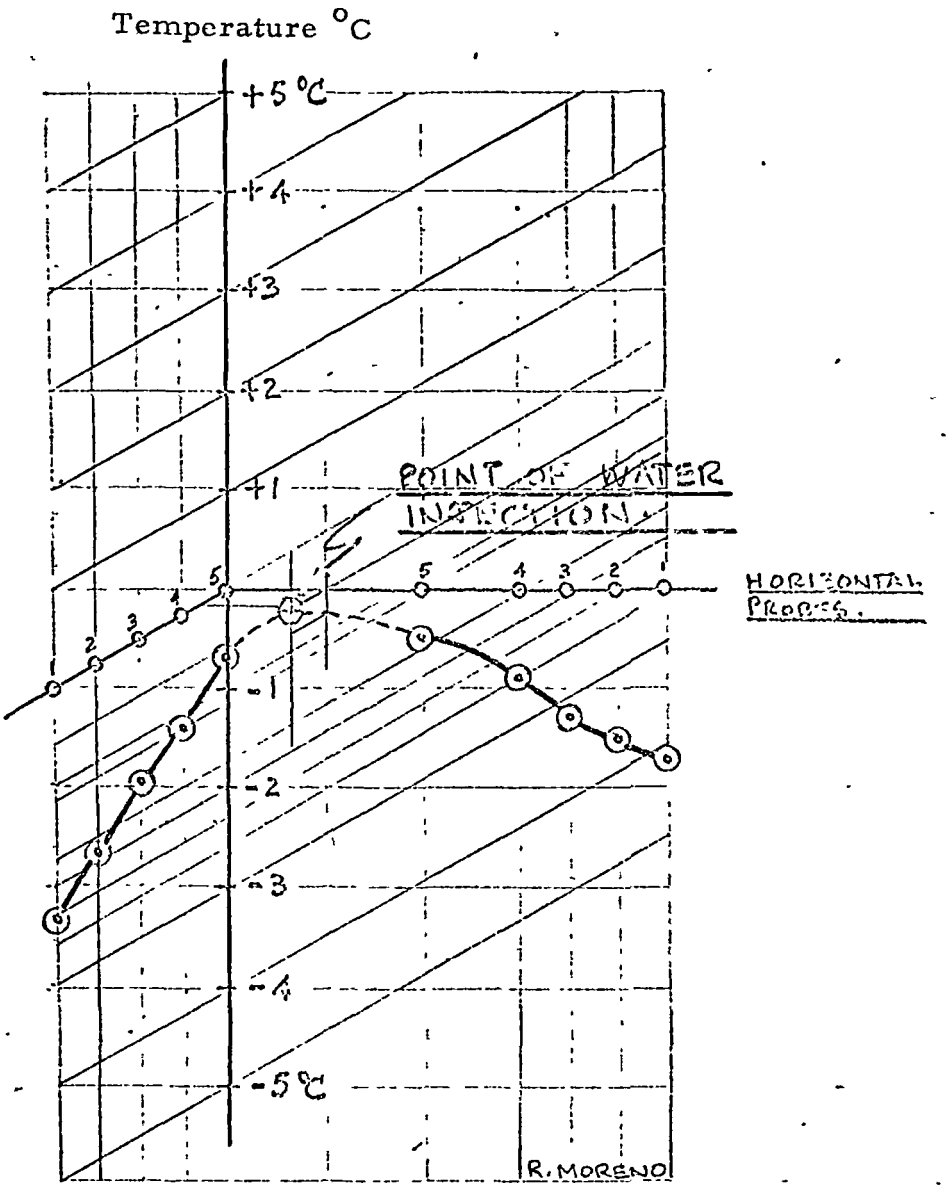
Pressure 6 Torr

Atmosphere CO_2

Frost Point (-) 40°C

Soil Temp. (+) 5.1°C

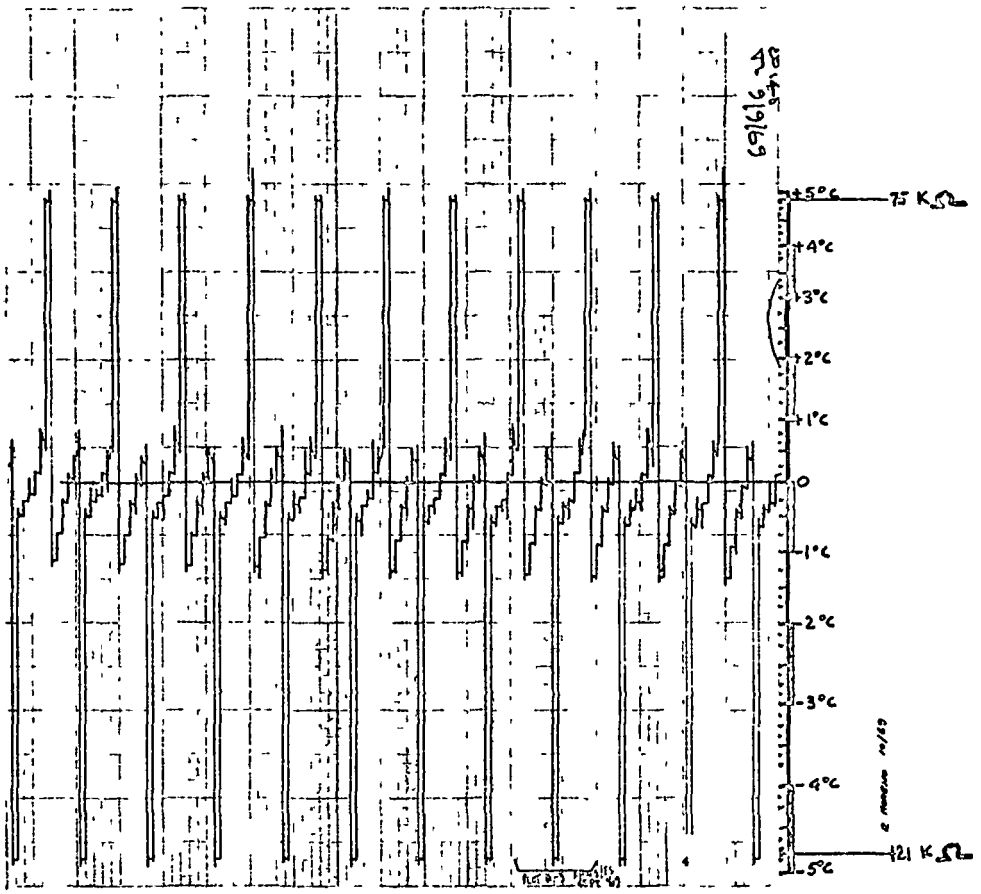
Mars Box Wall Temperature (+) 3.0°C



Research on Ice Barrier Moist Center Formation. Single Capillary Applicator.

An extreme condition: Complete freeze-up. Flow interrupted, applicator frozen. No moist center. Ice "Ball".
(Water Injection Rate Prior to Interruption by Total Freezing was Approximately 5 ml/hr.)

	Fig 53		
GI ICS INCORPORATED			
Rockville Maryland	12-69 Date	Init.	Scale
NAS2-5360 Cont. No	In Situ Life Detection on Mars Report Title		



Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 53

	Fig 54		
BI ... ICS INCORPORATED			
Rockville Maryland	12-69 Date		State
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		

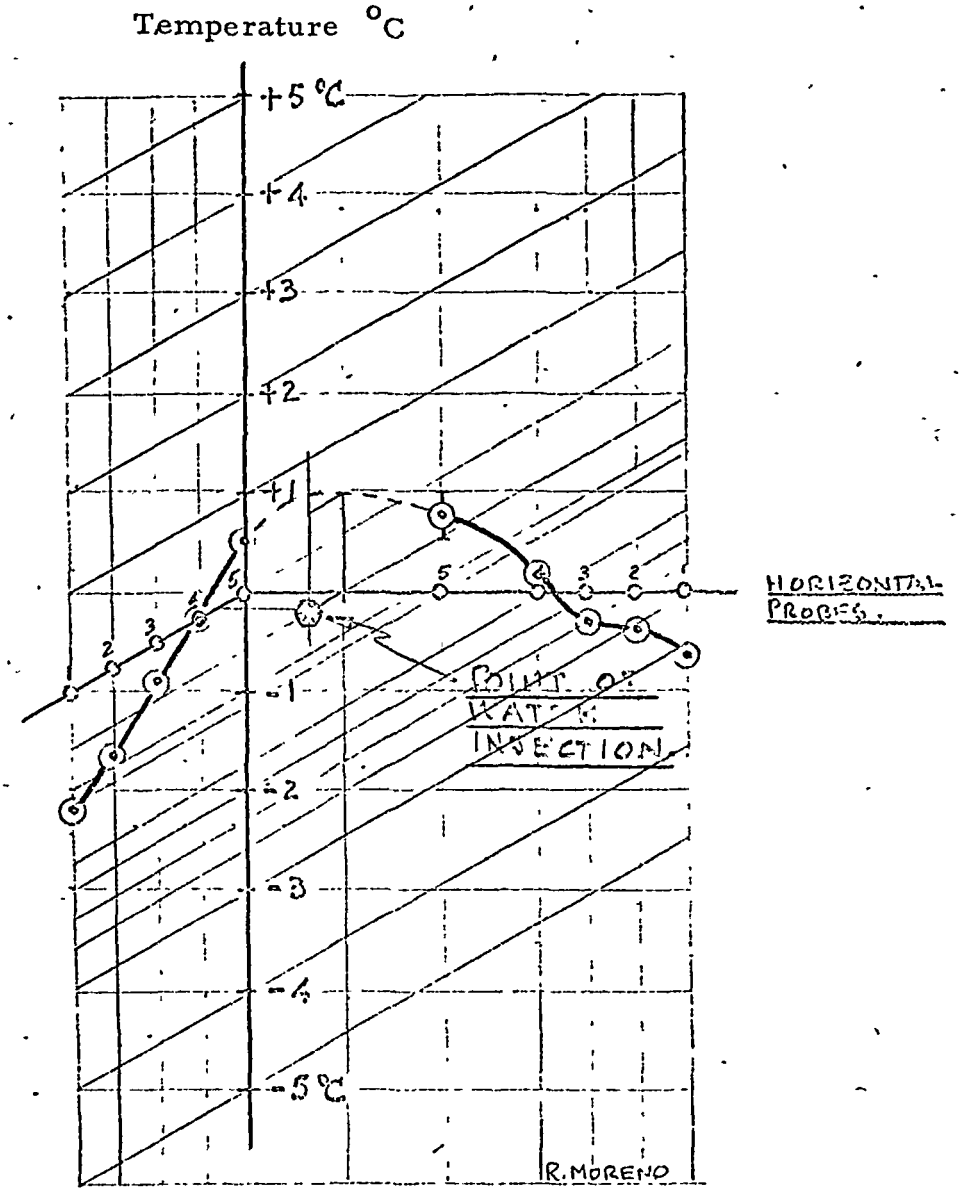
Pressure 6 torr

Atmosphere CO_2

Frost Point (-) 43°C

Soil Temp. (+) 35°C

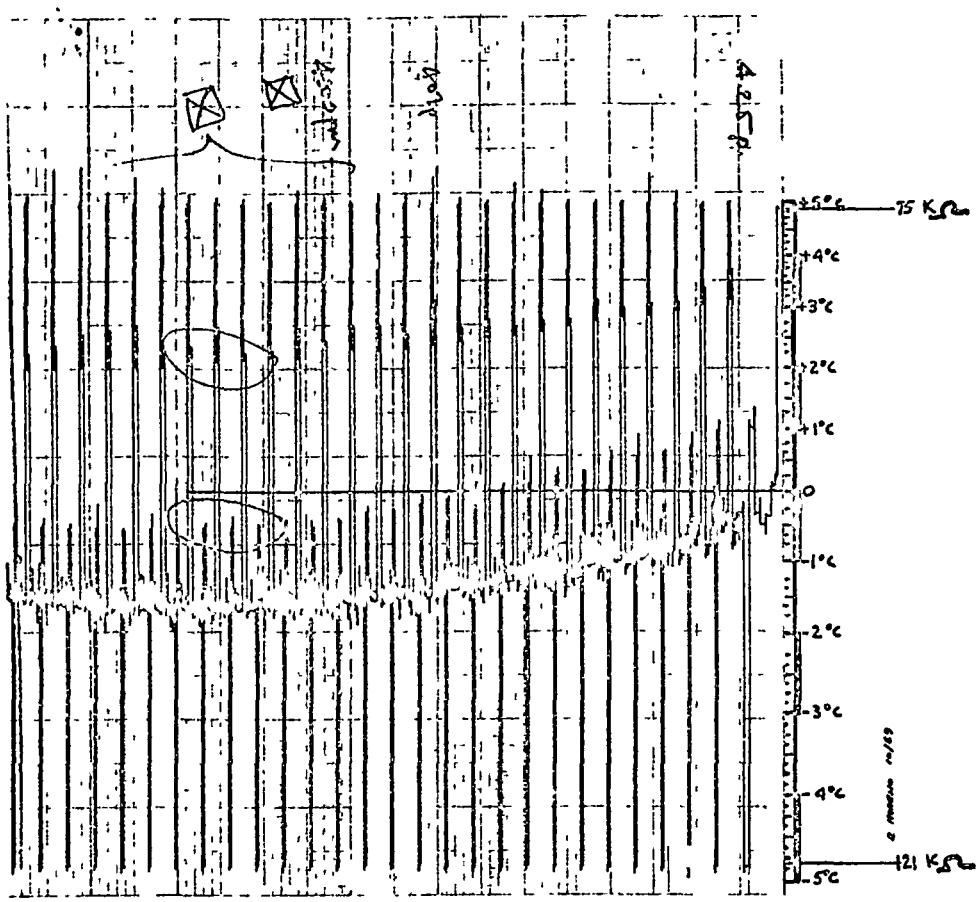
Mars Box
Wall Temp. (+) 45°C



Research on Ice Barrier Moist Center Formation. Single Capillary Applicator

"Moist-Center" -"Ice-Barrier" Configuration, Barrier Temperatures down to (-) 2° C in outer surface. Stability can be maintained but control is delicate. Any diminuation in injection flow or in temperature of injection water can lead to complete freeze-up very rapidly.

	Fig 55	
BI ICS INCORPORATED		
Rockville Maryland	12-69 Date	Scale
NAS2-5360	In Situ Life Detection on Mars	



Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 55

	Fig 56		
E[illegible]ICS INCORPORATED			
Rockville Maryland	Date 12-69	Init.	Scale
Cont No NAS2-5360	Report Title In Situ Life Detection on Mars		

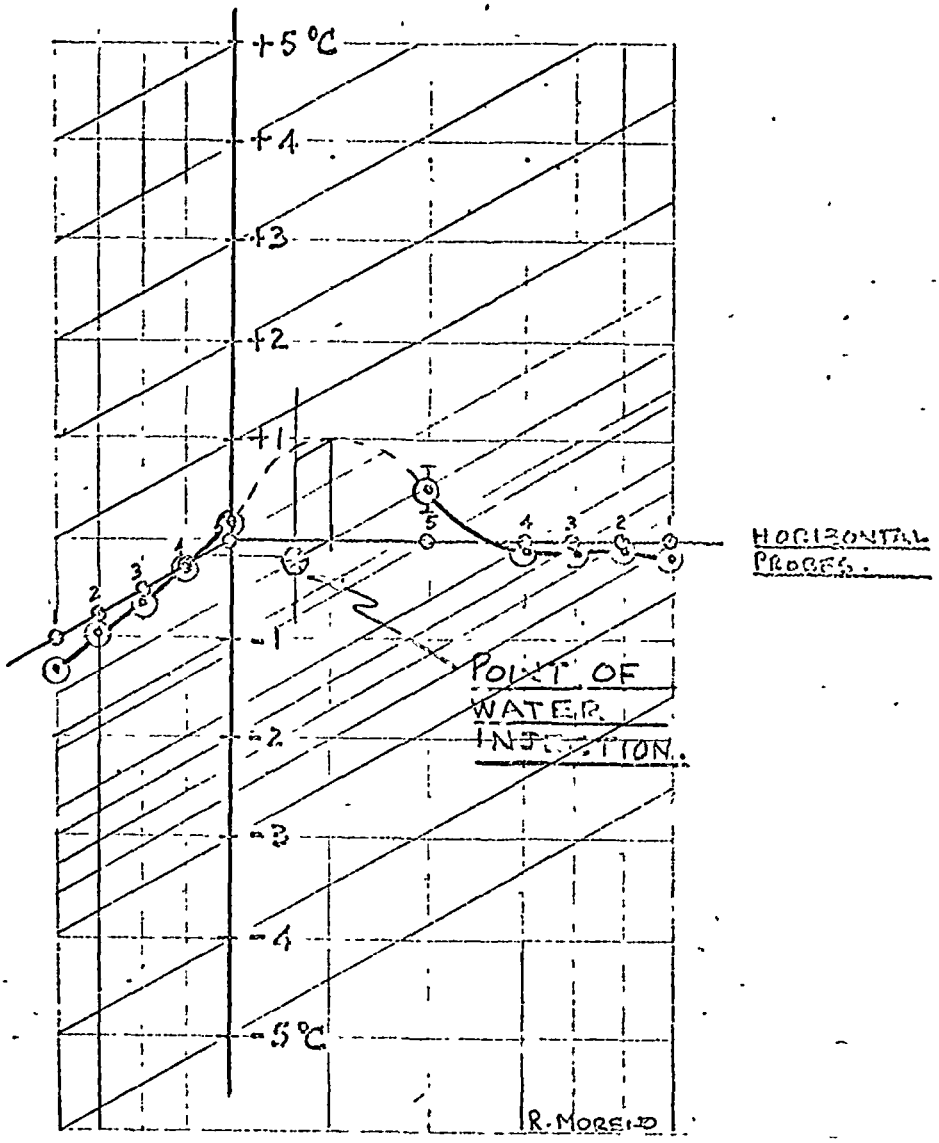
Pressure 6 torr

Atmospherc CO_2

Frost Point (-) 37°C

Soil Temp. (+) 6°C

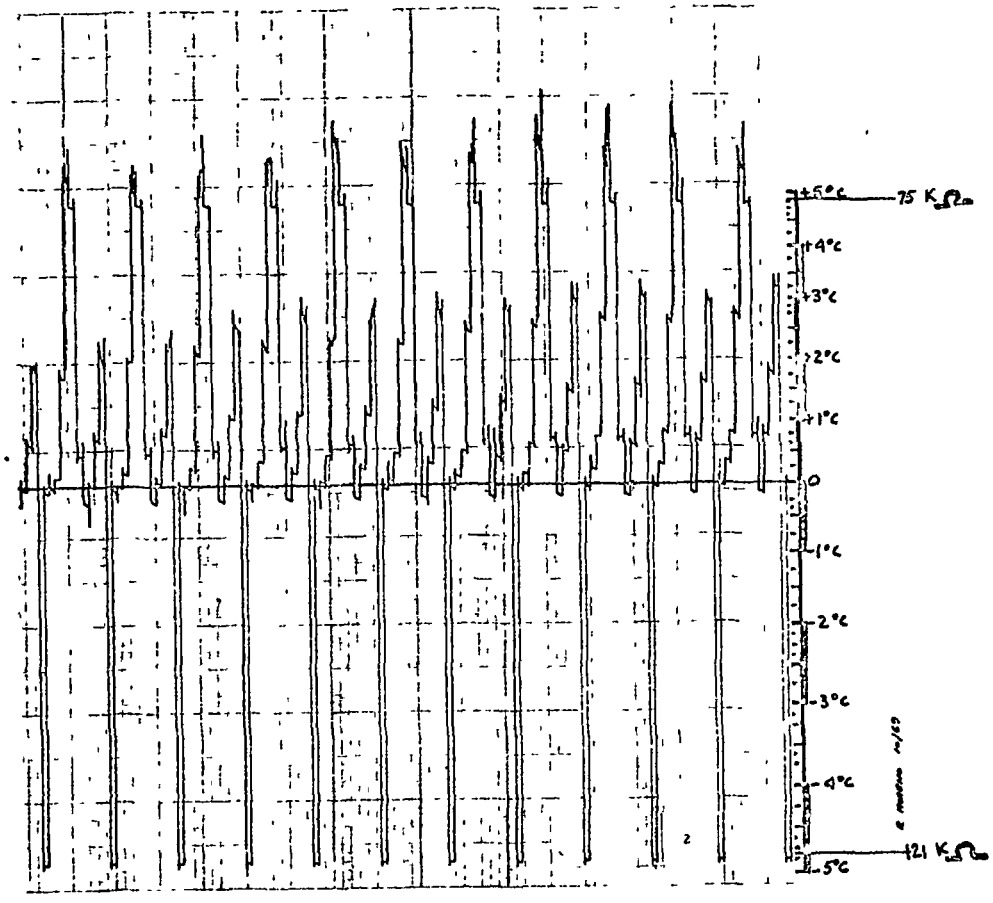
Mars Box Wall Temp. (+) 15.0°C



Research on Ice Barrier Moist Center Formation. Single Capillary Applicator

"Moist-Center" - "Ice-Barrier" Configuration. Good Condition. Stability can be maintained indefinitely. Barrier thickness good. Temperature of Barrier just below freezing. Moist core temperature adequate. Control margin not critical. (Water Injection Rate: Approximately 5 ml/hr.)

	Fig 57		
DI ICS INCORPORATED			
Rockville Maryland	Date 12-69	Init	Sect.
NAS2-5300	In Situ Life Detection on Mars		



Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 57

	Fig 58		
BI[illegible]CS INCORPORATED			
Rockville Maryland	12-69 Date		Scale
NAS2-5360	In Situ Life Detection on Mars		

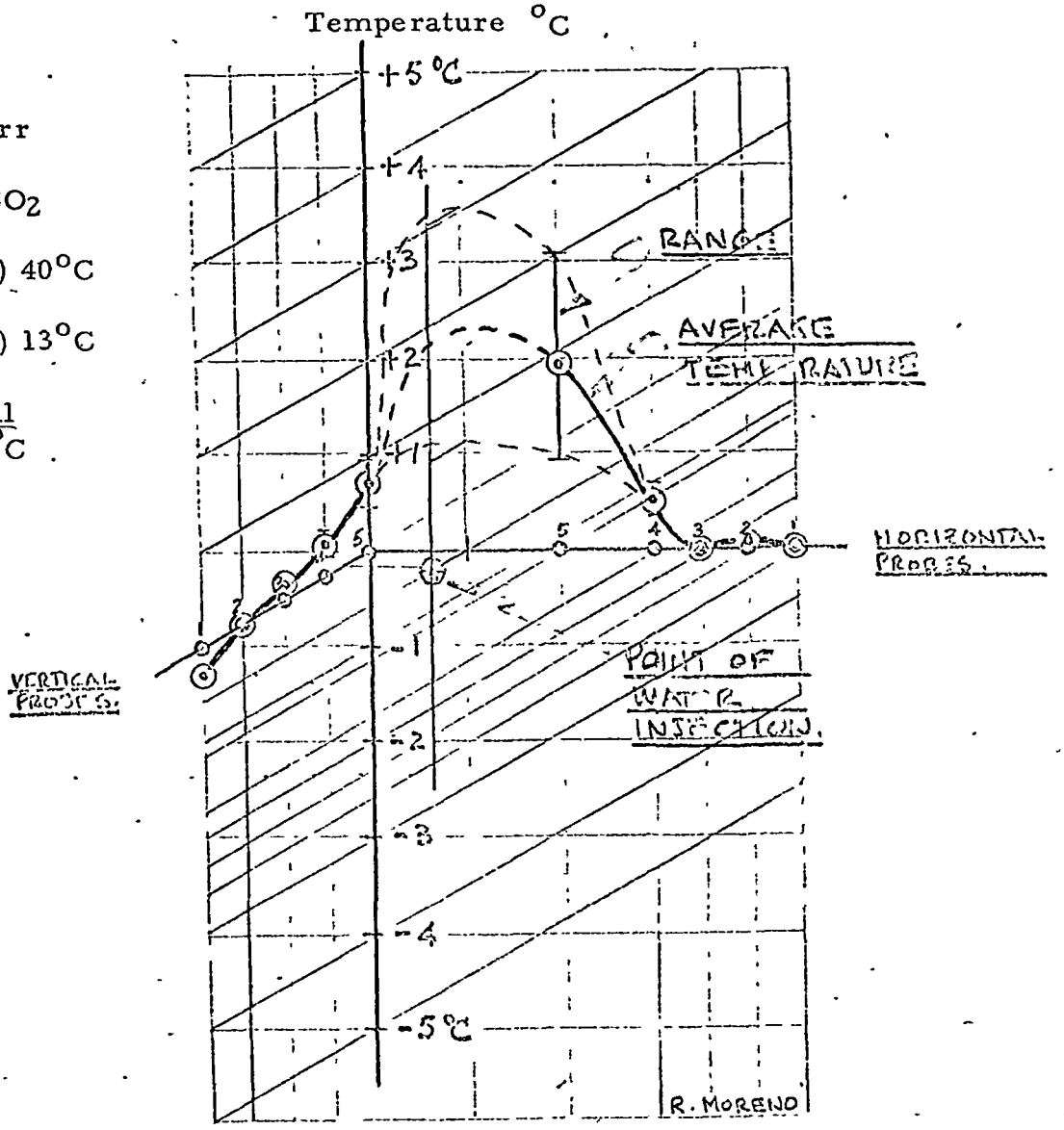
Pressure 6 torr

Atmosphere CO_2

Frost Point (-) 40°C

Soil Temp. (+) 13°C

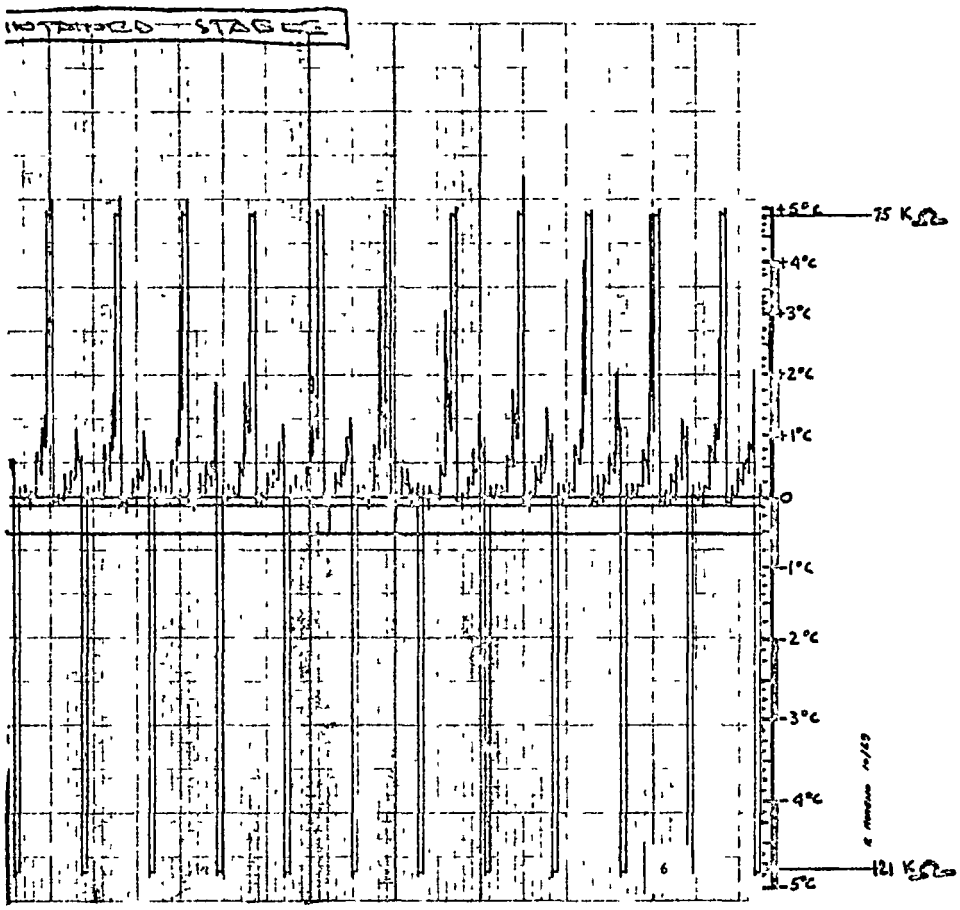
Mars Box Wall Temp. (+) 10°C



Research on Ice Barrier Moist Center Formation. Single Capillary Applicator.

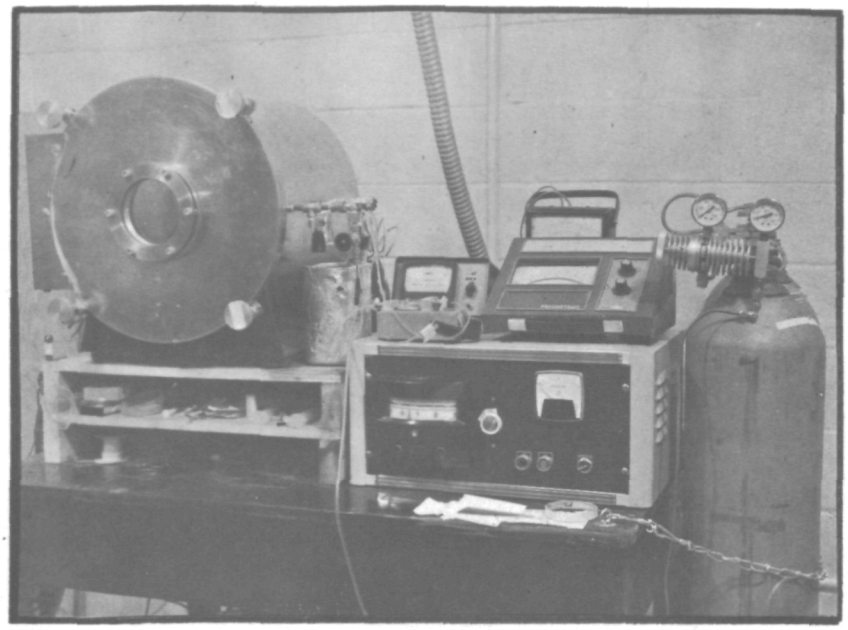
Optimum "Moist-Center" - "Ice-Barrier" Configuration. Stability can be maintained idefinitely. Barrier thickness good. Large moist-core volume. Moist core temperatures excellent. Ample margin for control. (Water Injection Rate: Approximately 5 ml/hr.)

	Fig 59		
EI ICS INCORPORATED			
Rockville Maryland	12-69 Date	Init	Scale
NAS2-5260	In Situ Life Detection on Mars		



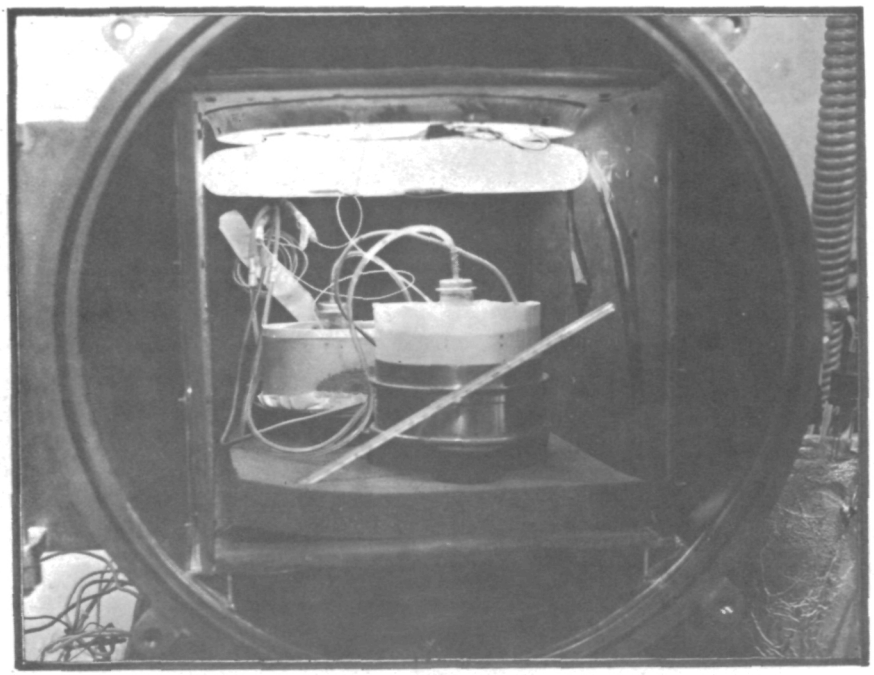
Research on Ice Barrier Formation
Strip-Chart Recorded Data Associated
with Figure 59

	Fig 60		
ICS INCORPORATED			
Rockville Maryland	12-69 Date		Scale
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		



Mars Environmental Simulation Facility

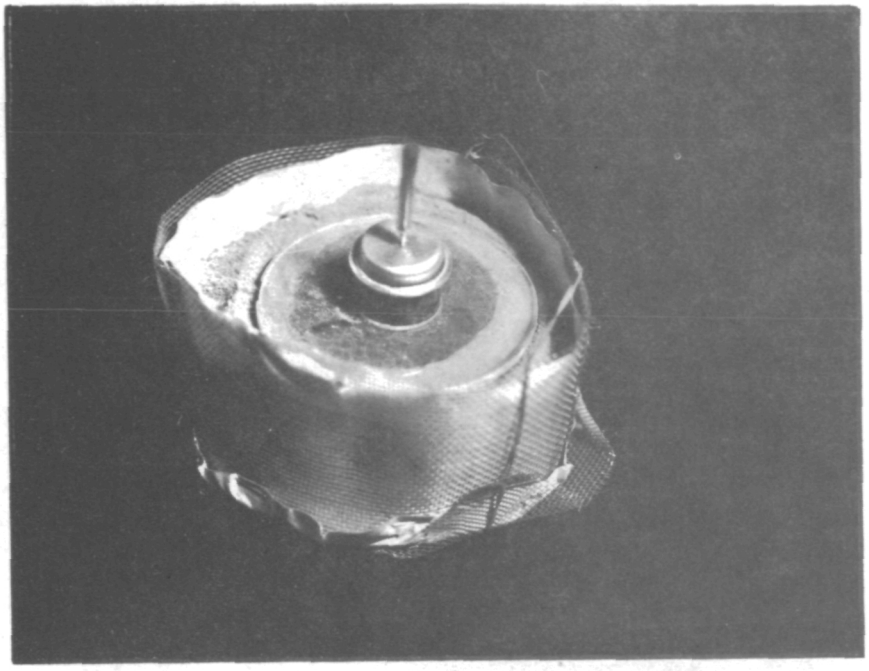
BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 61			
	Date 12-69	Init.	Scale	
Cont. No. NAS2-5360	Report Title In Situ Life Detection on Mars			



Mars Environmental Simulation Chamber

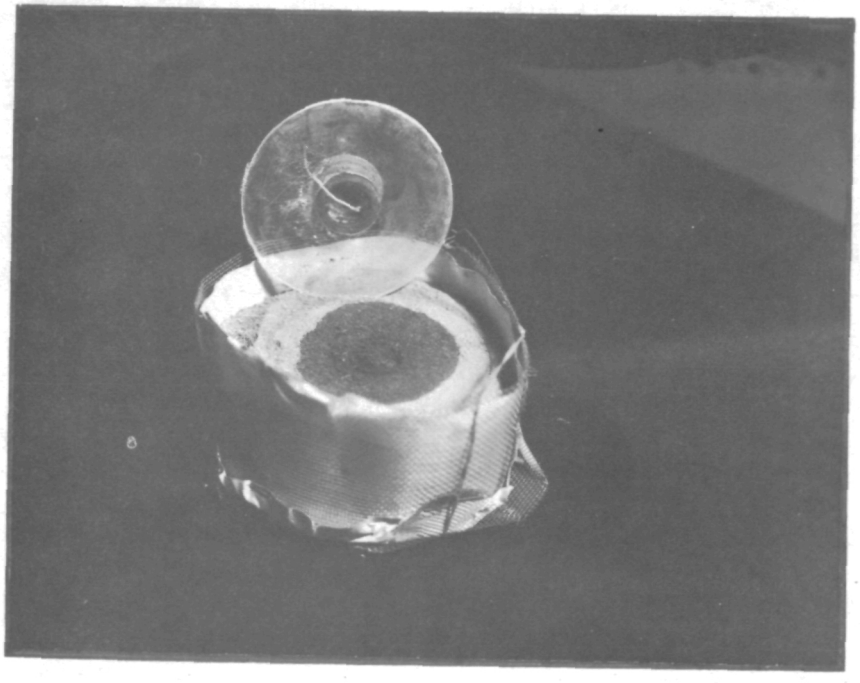
Duplicate Set-Ups for In Situ Life Detection Experiment Tests Utilizing the Ice Barrier-Moist Center Configuration.

BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 62			
	12-69 Date	Init.	Scale	
NAS2-5360	In Situ Life Detection on Mars			



(a)

(b)



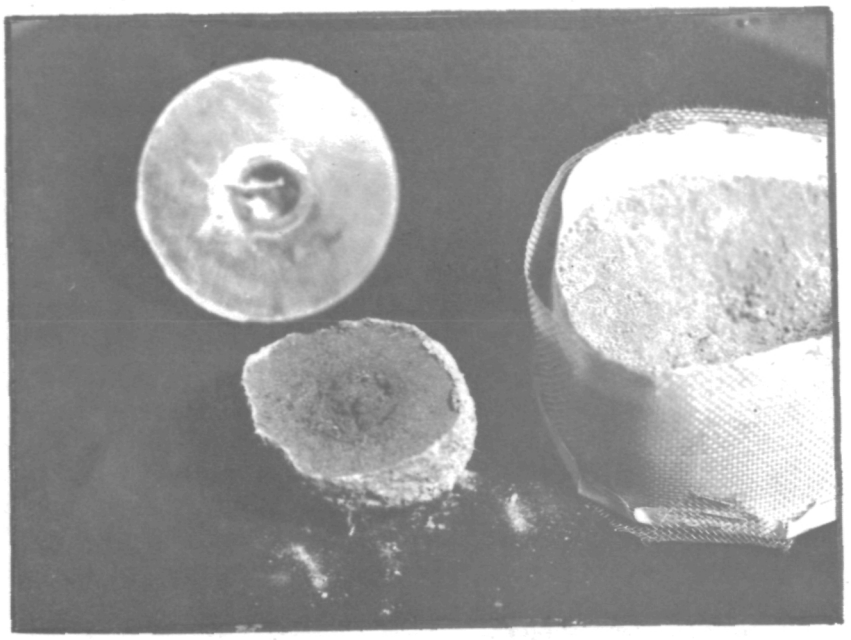
Ice Barrier-Moist Center Configuration

Mars Simulated Conditions.

(a) Experiment Set-Up.

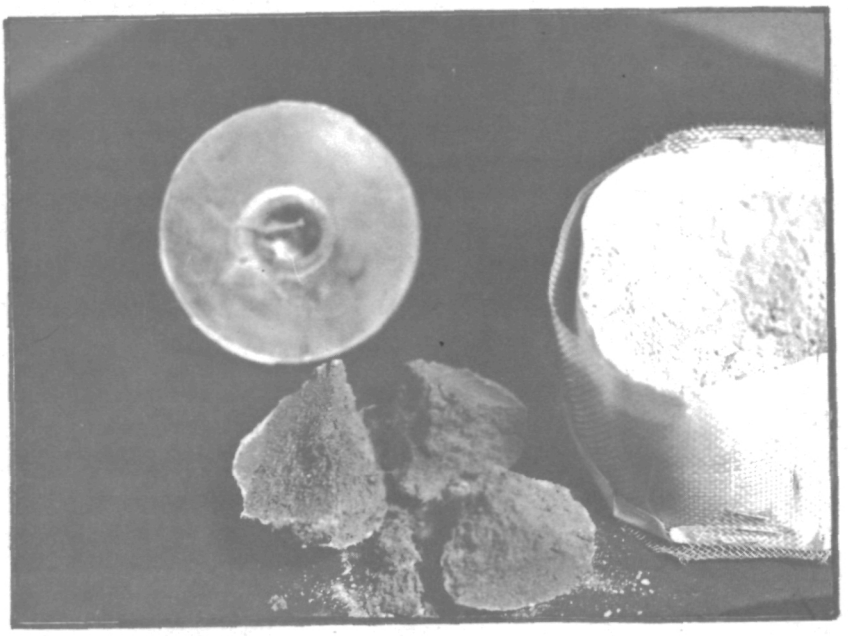
(b) Moist Soil Environment under Experiment Volume.

BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 63			
	Date 12-69	Init.	Scale	
NAS2-5360	In Situ Life Detection on Mars			



(a)

(b)



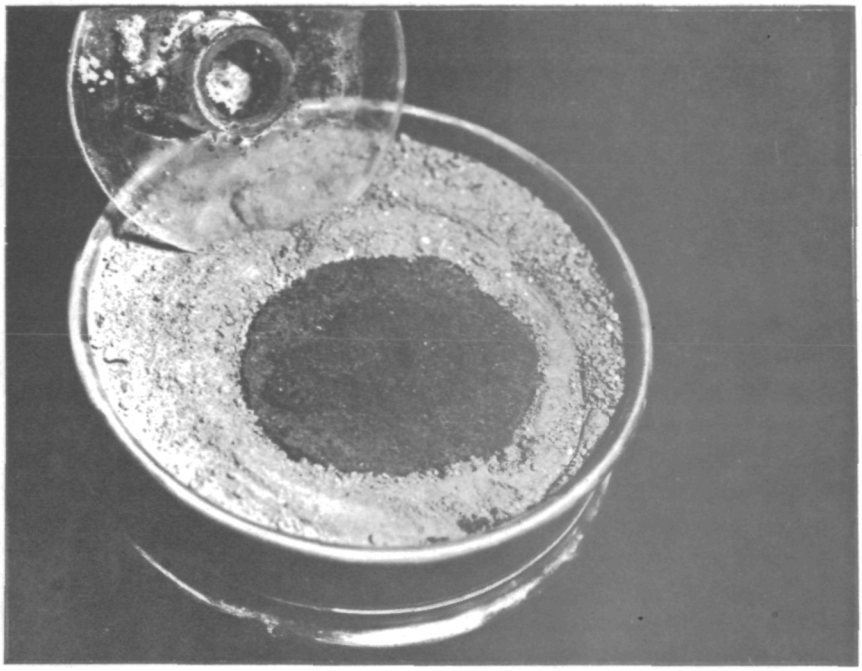
Ice Barrier-Moist Center Configuration

Mars Simulated Conditions.

(a) Ice Barrier-Moist Center Volume Removed from In Situ Sample Area.

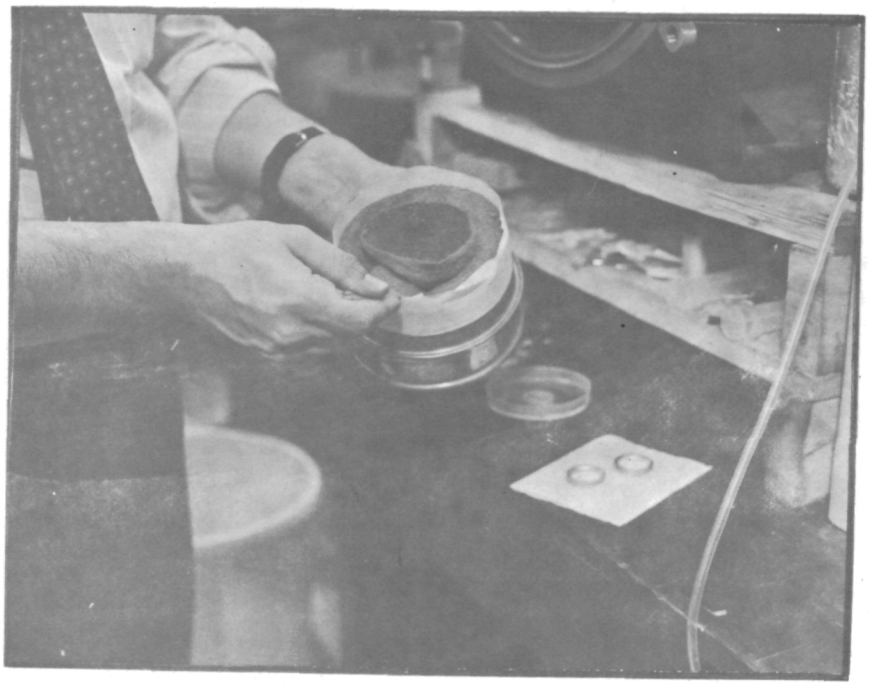
(b) Dissection to Show Moist Central Volume.

BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 64		
	12-69 Date	Init.	Scale
NAS2-5360	In Situ Life Detection on Mars		



(a)

(b)



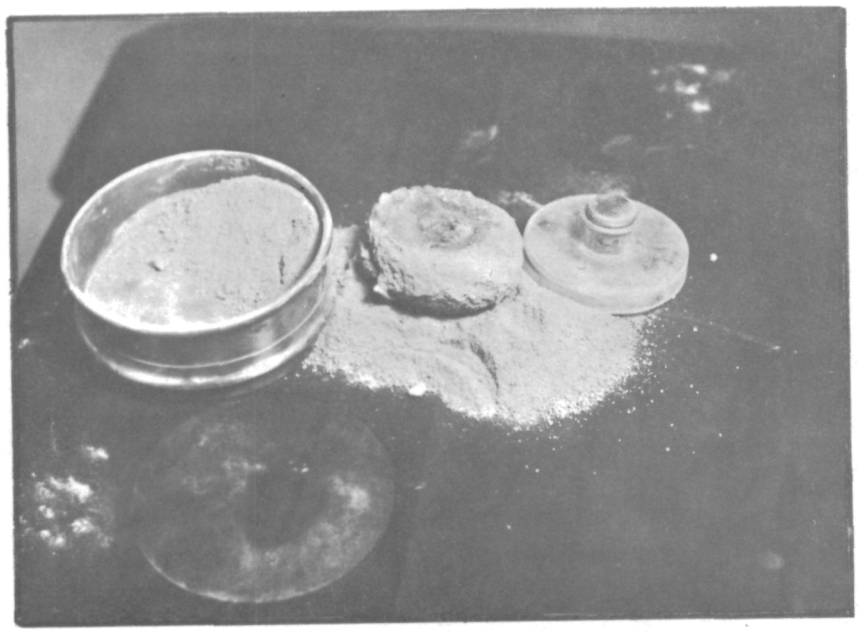
Ice Barrier-Moist Center Configuration

Mars Simulated Conditions.

(a) Moist Core in Soil.

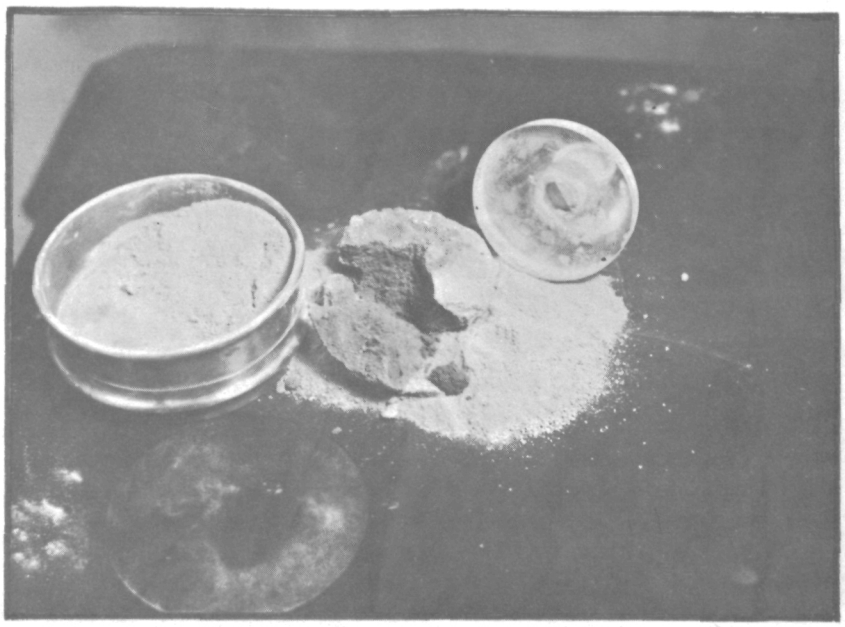
(b) Ice Barrier Configuration.

BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 65		
	12-69 Date	Init.	Scale
NAS2-5360	In Situ Life Detection on Mars		



(a)

(b)



Ice Barrier-Moist Center Configuration

Mars Simulated Conditions.

(a) Another Ice Barrier-Moist Center Volume Removed from In Situ Sample Area.

(b) Dissection to Show Moist Central Volume.

BIOSPHERICS INCORPORATED Rockville, Maryland	Fig. 66		
	12-69 Date	Init.	Scale
NAS2-5360 Cont. No.	In Situ Life Detection on Mars Report Title		

BIOSPHERICS INCORPORATED

A block diagram for a generalized in situ life detection system is shown in Figure 67. The overall system efficiency "∋" is a function of the efficiencies of the component parts and the influence of the environment in which the system operates per se and on the system components.

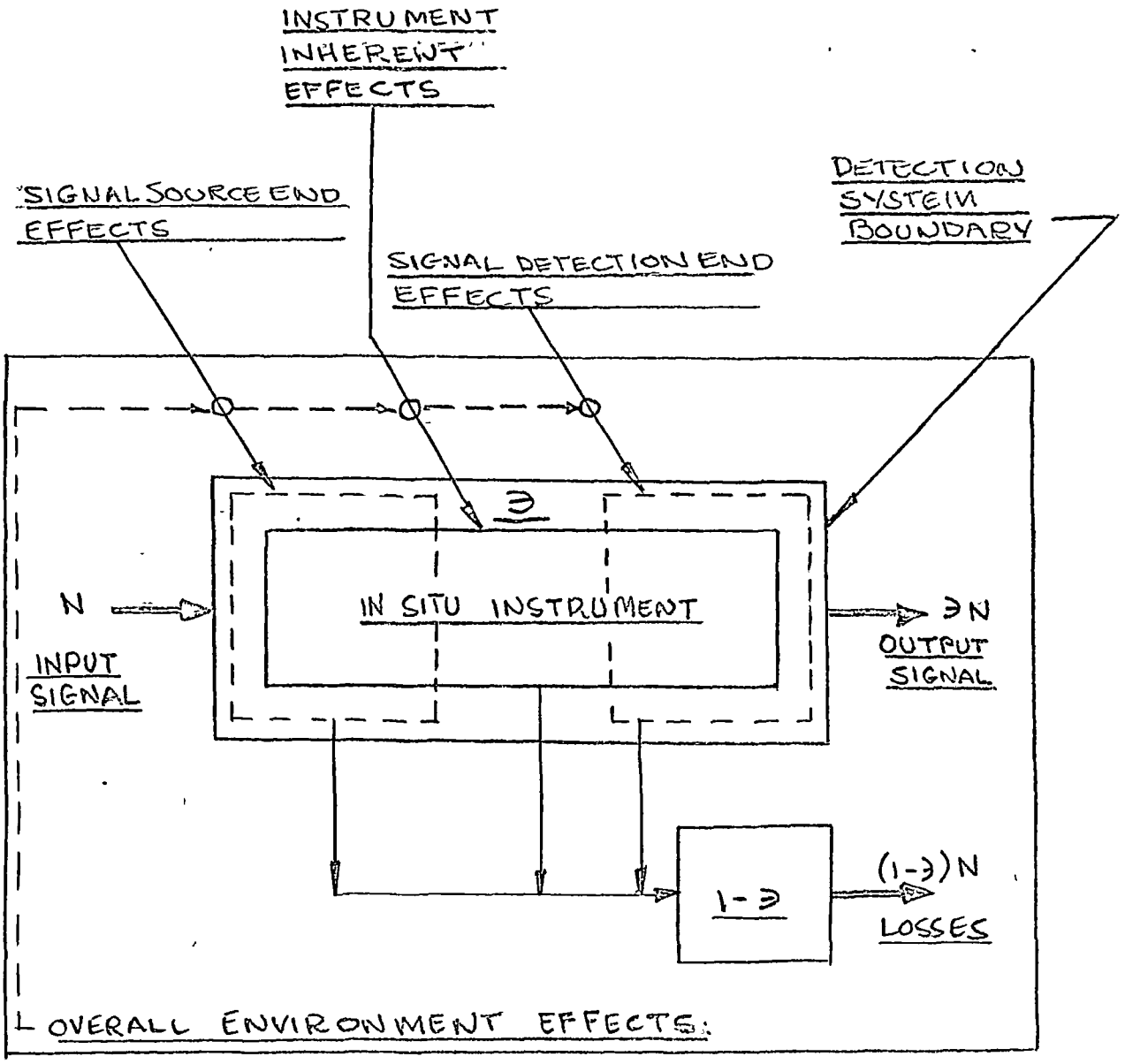
4.4-B Biological Response under Mars Simulated Conditions

Biological responses from terrestrial organisms were detected during tests under simulated Martian conditions. The ice barrier-moist center configuration developed in this program was used. The results obtained were very satisfactory and exceeded any obtained prior to the utilization of this technique.

Although specific quantitative information is not available on the attenuation of metabolic activity of the terrestrial organisms under the unusual stresses created by the simulated Martian conditions, a catastrophic attenuation undoubtedly occurs. Nonetheless, biological activity was clearly detected by the evolution of labeled CO_2 through metabolism of labeled nutrients by the Earth organisms under simulated Martian conditions. Results of the experiments are reported in Section 3.2-C of this report.

4.4-C Getter Efficiency

Closed volume tests were run to determine the gettering efficiency of the LiOH getter. A known amount of radio-



IN SITU LIFE DETECTION SYSTEM

BLOCK DIAGRAM.
SYSTEM EFFICIENCY.

BIOSPHERICS INCORPORATED, Rockville Maryland	Fig 67		
	12-69 Date	Init	Scale
NAS2-5360 Cont No	In Situ Life Detection on Mars Report Title		

active carbon dioxide was released in a sealed volume containing an LiOH-saturated getter pad essentially equal to those used in this study under the biology program. The getter pads duplicated the biology experiment pads in all respects. The radioactive gas was released chemically within the volume by adding excess sulfuric acid to a reaction vessel containing labeled sodium carbonate. The experimental apparatus for this experiment is shown in Figure 68.

Tests were run first in air at STP and then in carbon dioxide, also at STP. Gettering efficiency in the leakless, sealed volume was determined to be a "maximum" gettering efficiency for LiOH.

The results obtained were:

In Air: LiOH, max. $^{14}CO_2$ gettering efficiency - 97.7%

In CO_2 : LiOH, max. $^{14}CO_2$ gettering efficiency - 44.5%

4.4-D Overall In Situ Life Detection Efficiency

1. Introduction

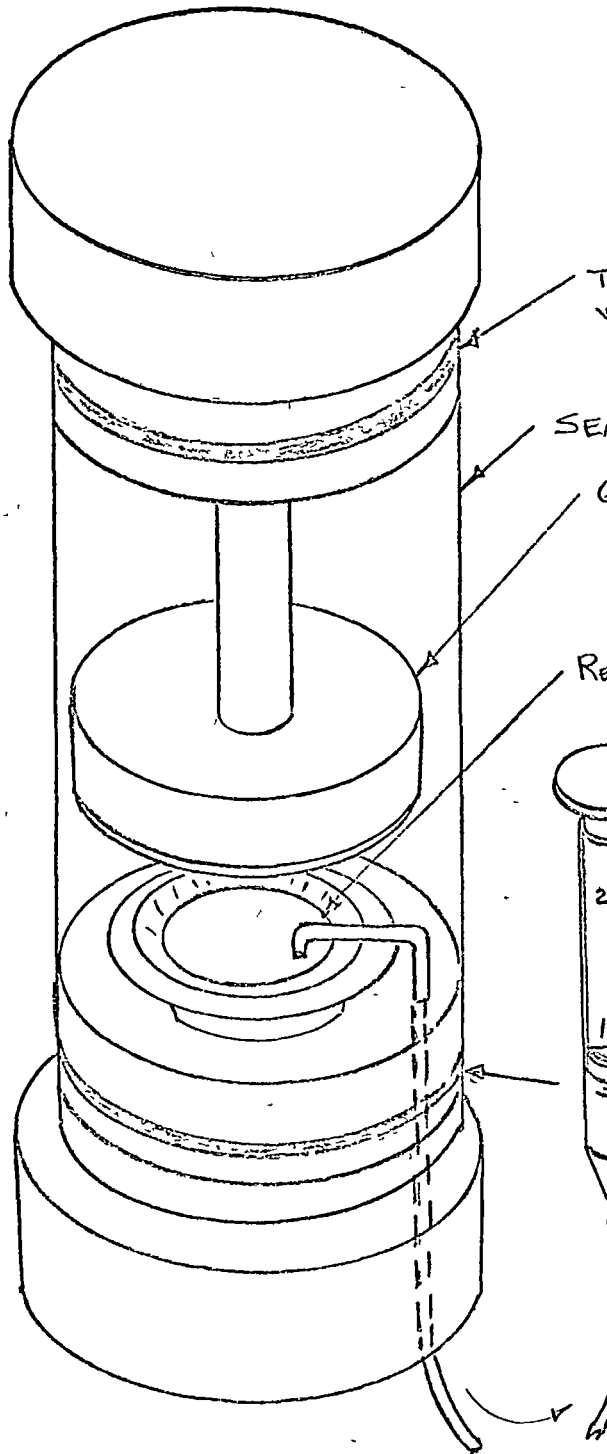
Numerous experiments were performed to determine efficiencies of the in situ life detection system under a variety of environmental conditions which included:

a. Air atmosphere at 6 torr - Dry Soil

b. CO_2 atmosphere at 6 torr - Dry Soil

c. CO_2 atmosphere at 6 torr - Wet Soil

d. CO_2 atmosphere at 6 torr - Wet Soil & various degrees of ice barrier seal to the in situ experiment volume.



— B. FORESTER 12/69 —

MAXIMUM $^{14}CO_2$ GETTERING
IN A SEALED VOLUME

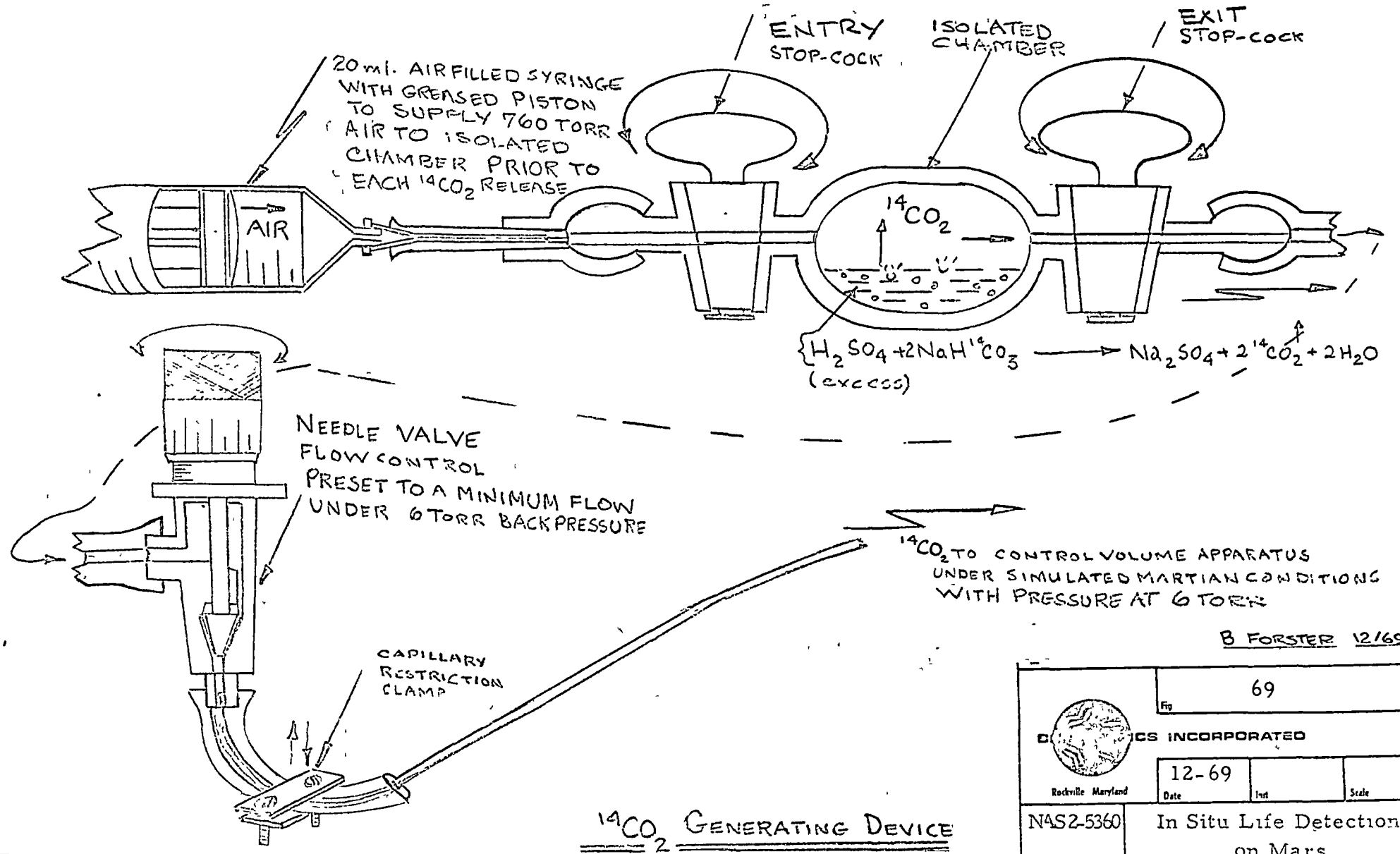
Rockville Maryland	Fig 68		
	12-69 Date	Init	Scale
NAS2-5300	In Situ Life Detection		

BIOSPHERICS INCORPORATED

2. Experimental Procedure

The generation of labeled CO_2 was accomplished in a specially designed gas generating device shown in Figure 69.

The purpose of the device was to allow the introduction of the labeled CO_2 into the in situ instrument under simulated Martian conditions at a controlled, regulated rate and a gas release pressure barely exceeding 6 torr to prevent violent disturbance of the soil either by local (in the soil) chemically released labeled gas under low atmospheric pressure (6 torr), or by high velocity flow in-rush into the in situ soil sample area from a labeled gas volume at 760 torr. This is accomplished by connecting the gas generating device to the Mars environmental chamber facility and to the in situ experiment volume through a chamber access penetration and capillary tubing. Once the connection and setting-up are accomplished, the "exit stopcock" is closed, and the Mars experimental chamber and tubing up to the "exit stopcock" brought down to 6 torr pressure. Through the "entry stopcock," chemical solutions are introduced into the "isolated chamber" by means of a hypodermic needle. The "entry stopcock" is then closed, and an air-filled syringe is fitted to the connection as shown in Figure 69. Next, the labeled gas is released into the in situ experiment volume.



$^{14}CO_2$ GENERATING DEVICE

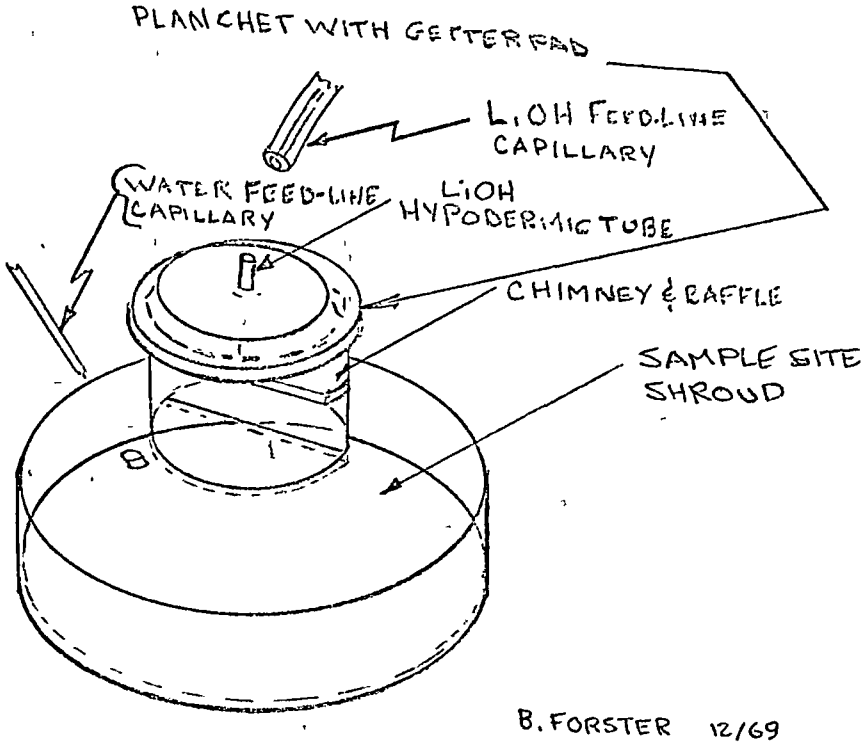
B FORSTER 12/69

	Fig 69		
DYNAMICS INCORPORATED Rockville Maryland	12-69 Date	Init	Scale
NAS2-5360	In Situ Life Detection on Mars		

Once the ice barrier-moist center configuration in the in situ experiment volume is established, the labeled gas is released into the in situ experiment volume through a needle valve flow control by opening the "exit stopcock." The valve is preset to release at a minimum flow when 760 torr are upstream of the valve and 6 torr downstream. After a period from one to several hours, the "exit stopcock" is closed permanently, the experiment allowed to continue for a given time, and the residual activity in the "isolated chamber" determined.

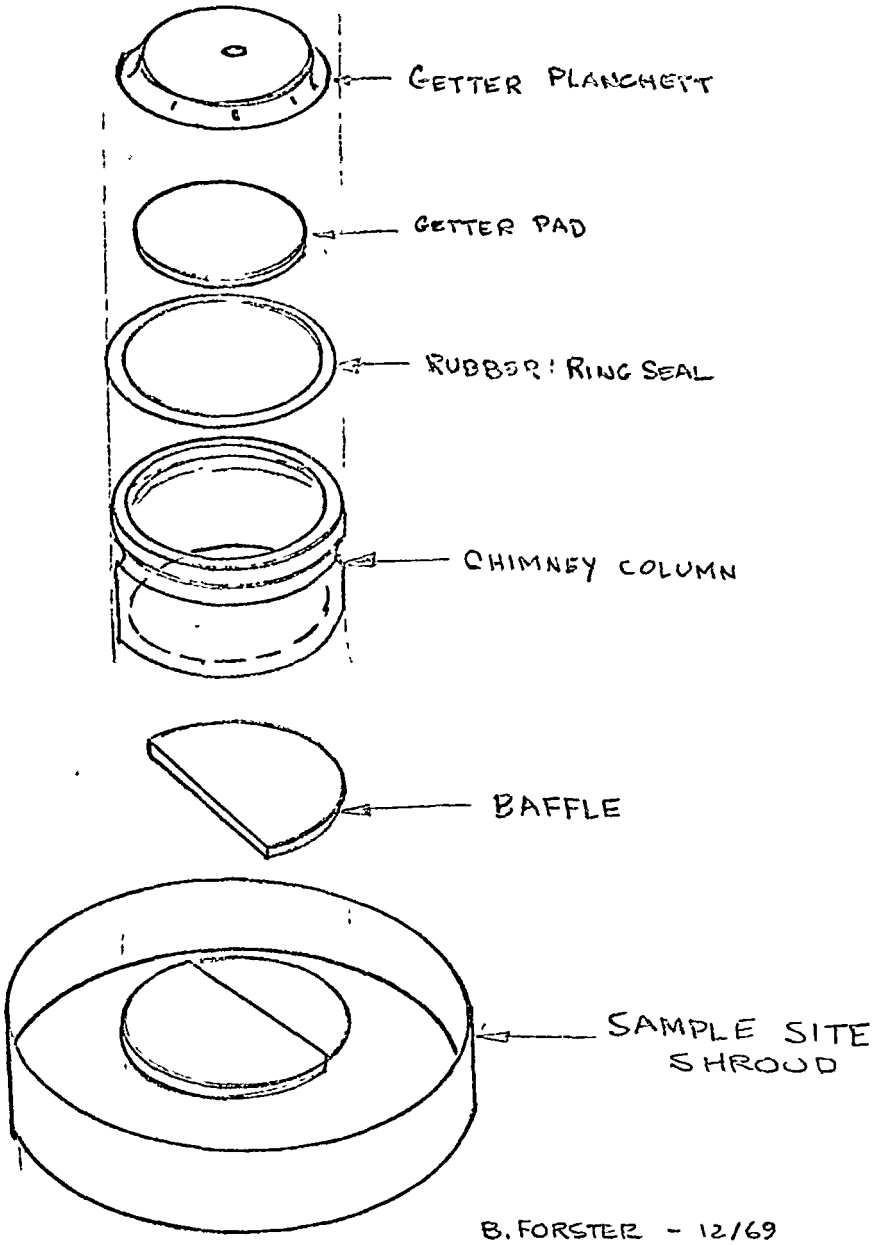
An important part of the experiment is the function of the air-filled syringe. Periodically, during the release of the labeled gas into the in situ experiment, the "exit stopcock" is closed and the "entry stopcock" opened to allow air from the syringe to enter the "isolated chamber" which is at a lower pressure. Once the pressure equilibrates to 760 torr, the cock is closed, and the "exit stopcock" opened again. In effect, this procedure ensures the purging out of practically all of the labeled gas into the experiment volume and the periodic maintenance of the 760 torr to 6 torr gradient across the needle valve.

Figures 70 and 71 show the experiment volume used in the tests. It consists of a soil-area shroud, a chimney-type structure, and a getter pad assembly. A pair of baffles placed in the chimney prevent any soil particles soaked with labeled nutrient from possibly trav-



CHIMNEY EXPERIMENT VOLUME

BIOCS INCORPORATED Rockville Maryland	Fig 70		
	12-69 Date	Init	Scale
NAS2-5360	In Situ Life Detection on Mars		



CHIMNEY TYPE EXPERIMENTAL VOLUME

(EXPLODED VIEW)

	Fig 71		
ICS INCORPORATED			
Rockville Maryland	12-69 Date	Ini	Scale
N°S2-5360	In Situ Life Detection on Mars		

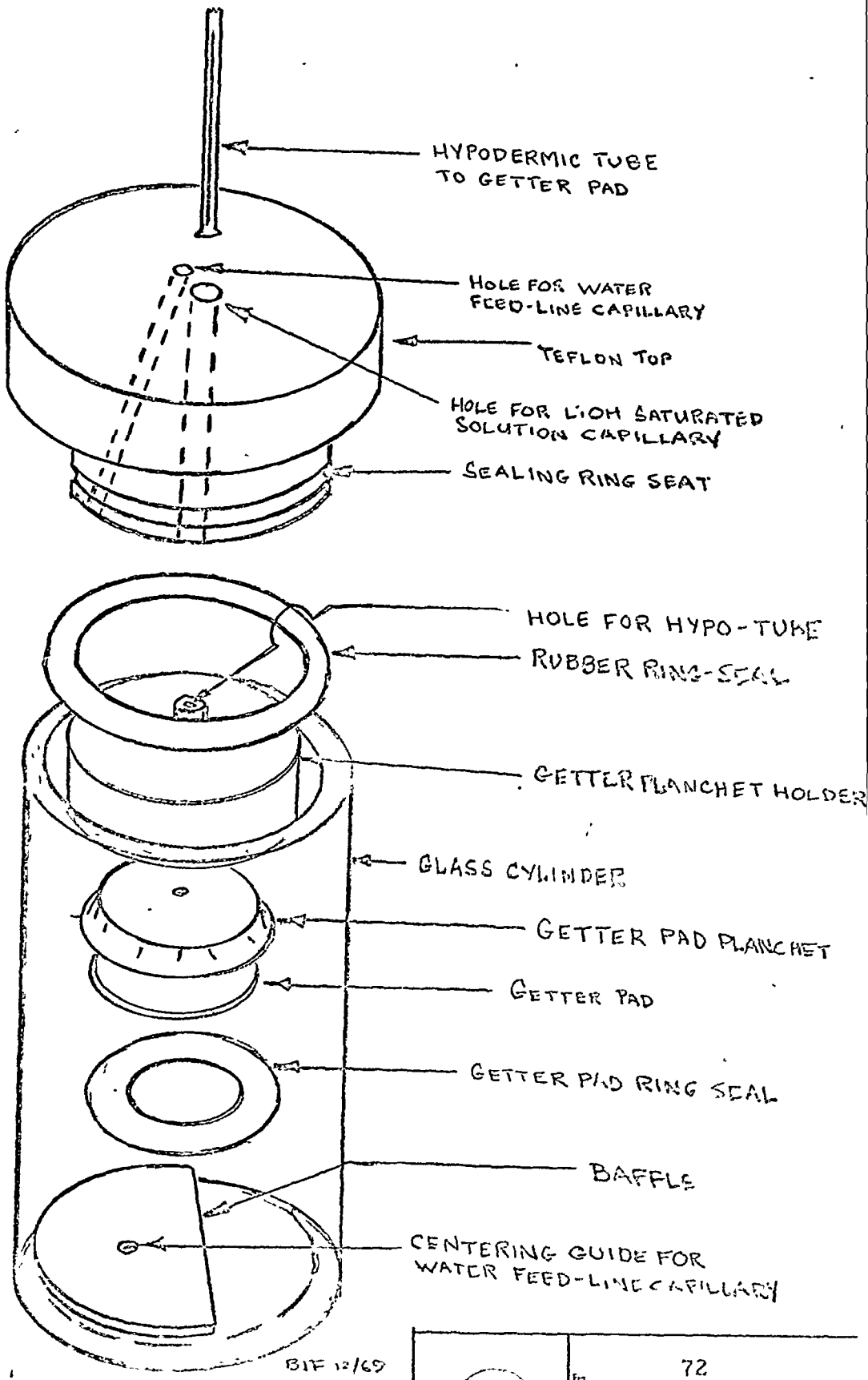
cling up the chimney and depositing on the getter pad.

In order to observe the signal detected as a function of the effectiveness of the ice barrier seal to the experiment volume, a "modified experimental volume" was used. It consisted basically in a reduction of the diameter of the original soil sample shroud. It was implemented by using a glass cylinder housing, and as before, a getter pad assembly. With this arrangement, it was easy to obtain an ice barrier of a diameter sufficient to obtain a seal with the glass cylinder within a short time. The "modified experiment volume" and an experimental set-up are depicted in Figures 72, 73, and 74.

4.4-E Results

The very definite influence of seal effectiveness between the ice barrier in the soil and the experiment volume shroud can be seen in the detection efficiencies listed below for the various conditions indicated:

Conditions:	Detection Efficiency:
(a) CO_2 at 6 torr (Mars) Dry Soil	0%
(b) Air at 6 torr Dry Soil	0.3%
(c) CO_2 at 6 torr (Mars) Wet Soil Ice Barrier-Moist Center	0.8%



EXPLODED VIEW

MODIFIED EXPERIMENT VOLUME

	Fig 72		
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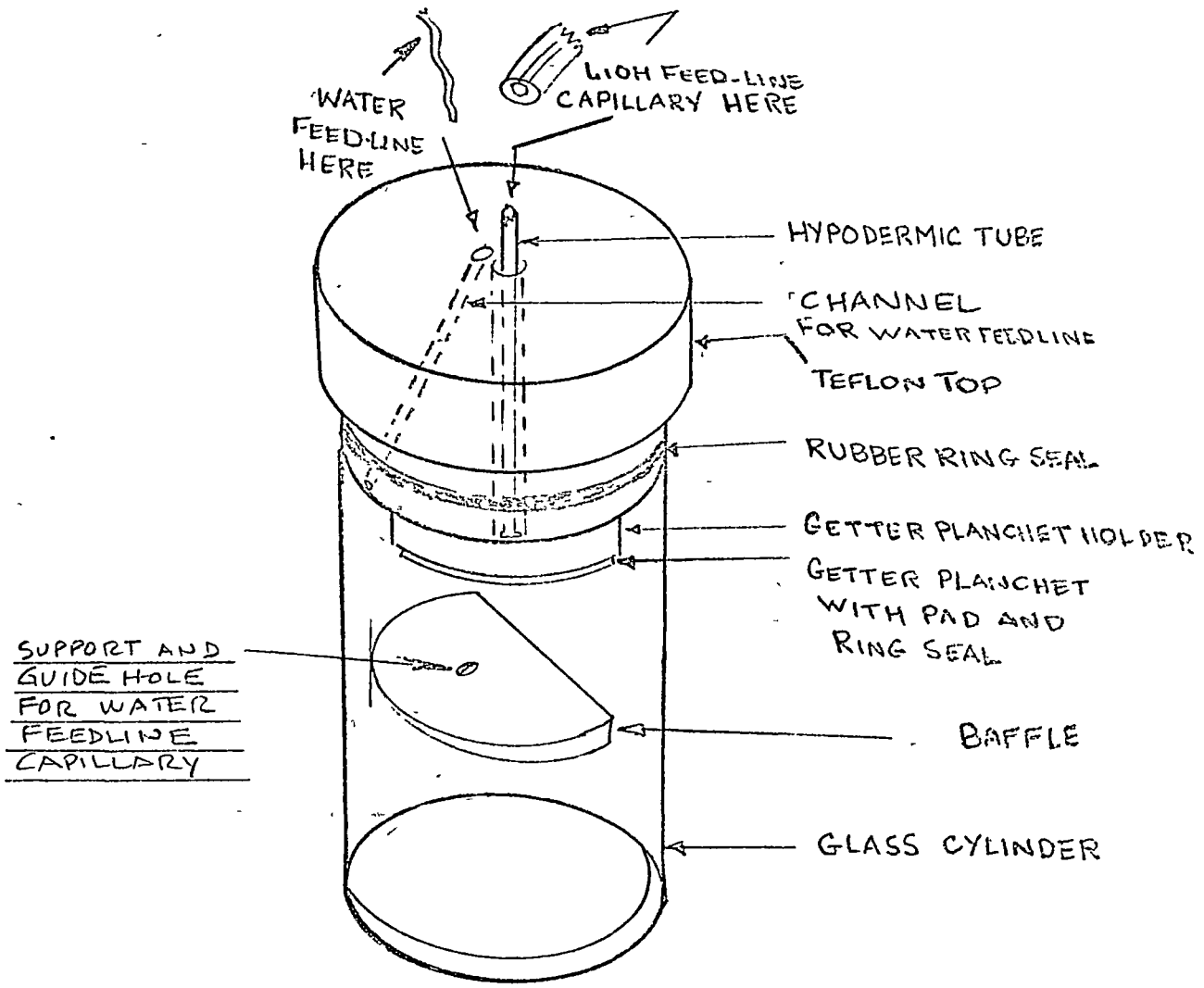
Rockville Maryland	Date 12-69	Ltr	Scale
NAS2-5360	In Situ Li[illegible] Detection		



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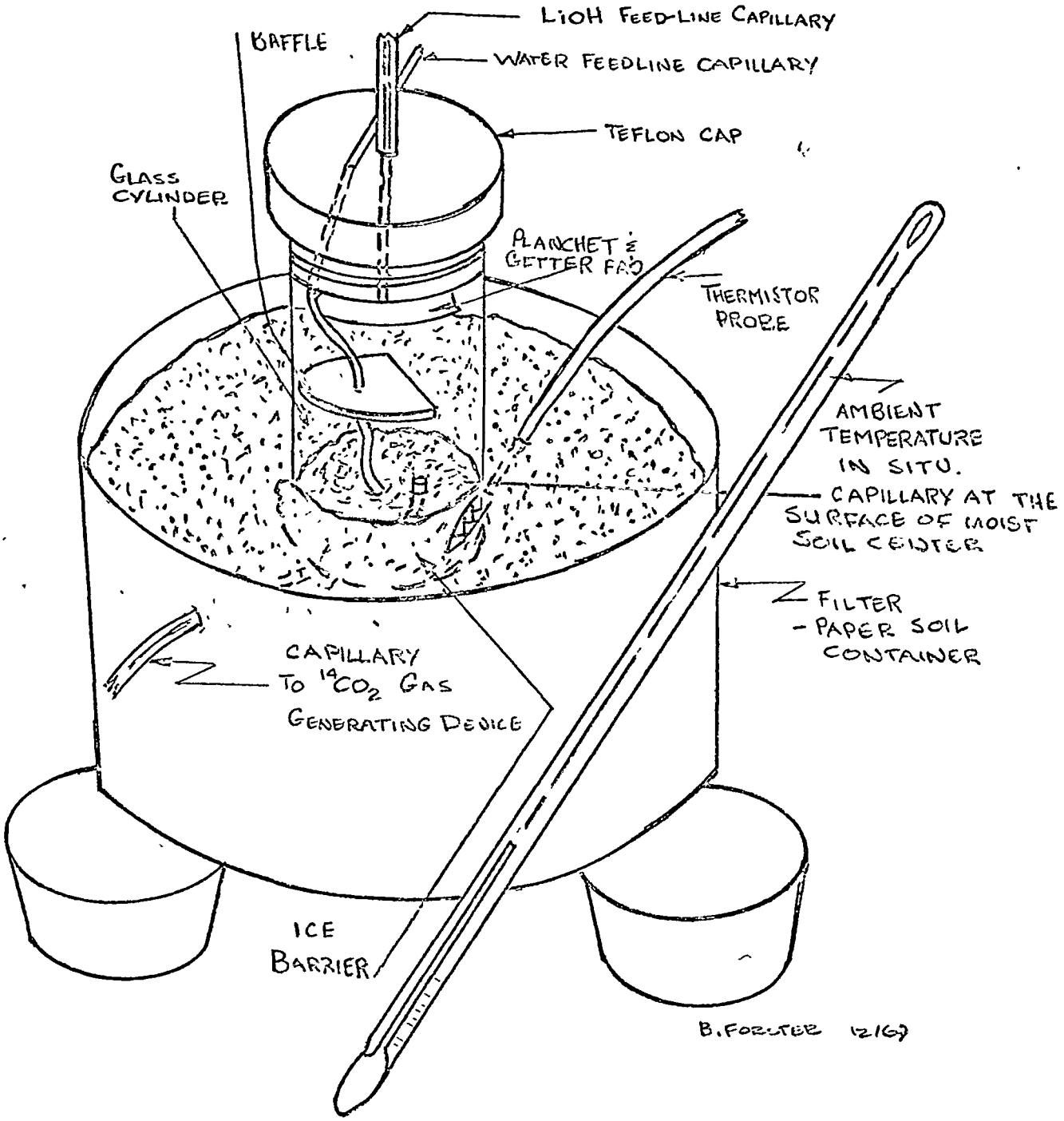
MODIFIED EXPERIMENT VOLUME

Rockville Maryland	Fig 73		
CS INCORPORATED			
	12-69 Date	Ind	Scale
NAS2-5360	In Situ Life Detection		



INORGANIC RESPONSE IN SITU EXPERIMENT.
MODIFIED EXPERIMENT VOLUME

	Fig 74		
ICS INCORPORATED			
Rockville Maryland	12-69 Date		Scale
NAS2-5350	In Situ Life Detection		

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Conditions	Detection Efficiency:
(d) CO_2 at 6 torr (Mars) Wet Soil Icc Barrier-Moist Center Observed Ice Seal to Volume Shroud	2.7%
(e) CO_2 at 6 torr (Mars) Wet Soil Ice Barrier-Moist Center Ice Seal, approx. 80%	3.5%
(f) CO_2 at 6 torr (Mars) Wet Soil Ice Barrier-Moist Center Ice Seal appeared to be approx. 90%	6.5%
(g) CO_2 at 6 torr (Mars) Wet Soil Ice Barrier-Moist Center Ice Seal "excellent", approx. 95%	7.5%
(h) CO_2 at 6 torr (Mars) Wet Soil Ice Barrier-Moist Center Ice Seal 100%	11.0%

The experiments with biological response mentioned above and reported in Section 3.2-C had a seal configuration of approximately 3.5% gettering efficiency - see (e) above. The results even at this level of efficiency and at this very preliminary stage of design of an in situ life detection "instrument" were easily recognizable and definite indication of biological activity in the soil sample from Earth organisms under Martian stress environment, and they demonstrate clearly that an in situ life detection system under simulated Martian conditions

is feasible. Obviously, the better the seal the better the results. For radioactive carbon detection techniques, a 3% to 5% efficiency is already a very acceptable level of detection.

4.5 Proposed Concept for In Situ Instrument Design and Life Detection System Implementation

Based on the utilization of the single capillary applicator and the maintenance of the ice-barrier configuration method, we have evolved a conceptual design for an in situ instrument for life detection by means of labeled release tests.

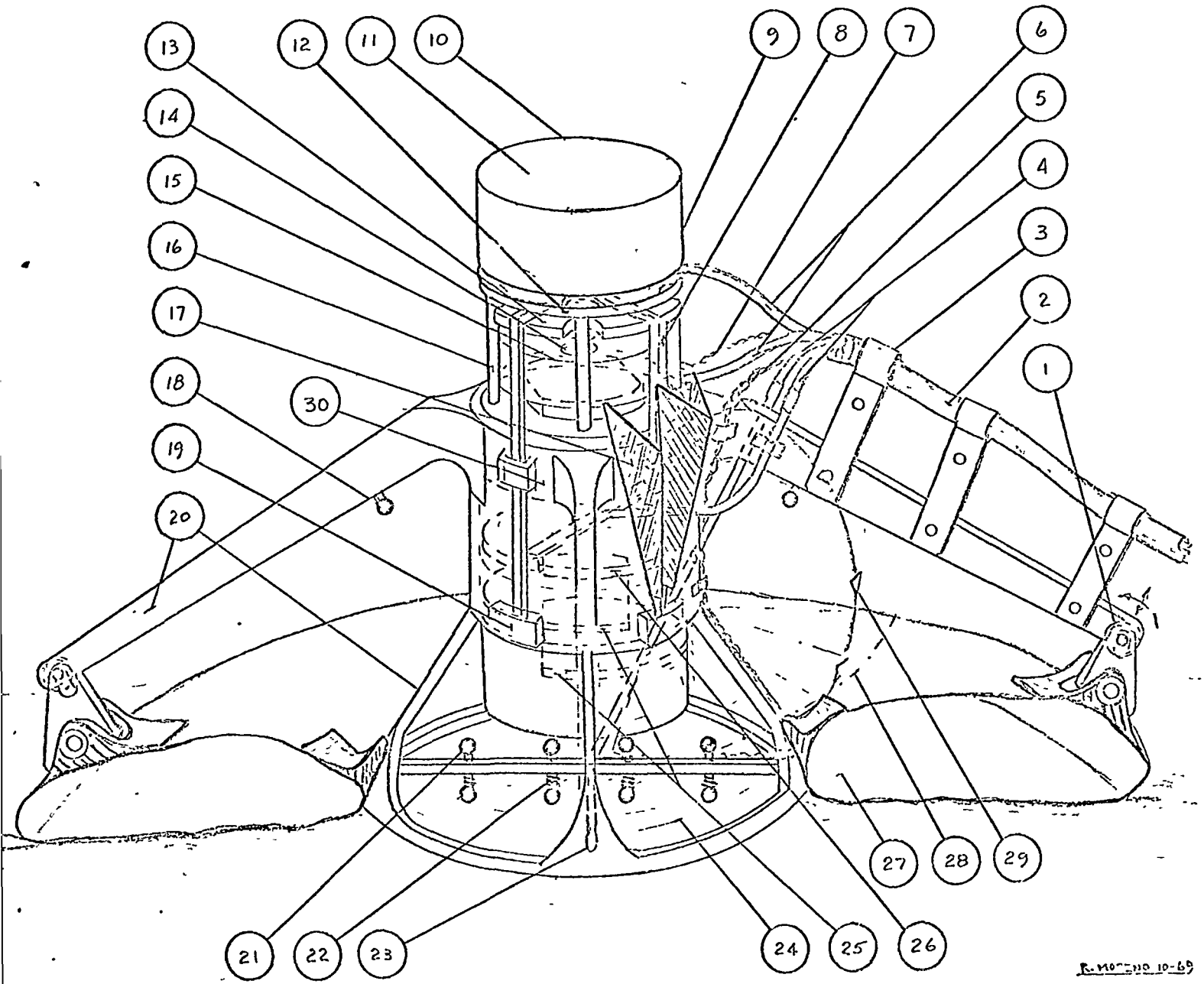
The concept for the instrument being proposed consists of an integrated system embodying all the requirements for successful in situ operation.

The design is based on the techniques developed at Biospherics during this feasibility study and presents an advanced solution to the problem of implementation and breadboarding.

Figure 75 shows the conceptual design and arrangement of the instrument and its component parts.

Figure 76 is a block diagram indicating the functional and support equipment required for inclusion aboard a Mars lander vehicle.

For descriptive purposes, the instrument is shown fitted to perform the labeled release experiment. The supporting structure consists of four arms extending out radially from the central cylin-



SCALE:
APPROX FULL SIZE

FIG.-75- IN SITU INSTRUMENT
MARS LIFE DETECTION EXPERIMENT
(CUT-AWAY PHANTOM VIEW)

1	KNEE JOINT, TWO DEGS. OF FREEDOM	13	SHADE ACTUATOR PLATE	25	GAS AND LIGHT BAFFLES.
2	UMBILICAL CORD.	14	SPRING.	26	GETTER HOLD DEVICE.
3	CABLE ANCHOR AND SUPPORT	15	IMPULSE SOLENOID COIL.	27	SOFT PLASTIC CONTAINER. LIQUID FILLED
4	H_2O AND LiOH SUPPLY LINES.	16	STRUCTURAL SPACERS.	28	SHADE, DEPLOYED POSITION.
5	THERMISTOR LEADS	17	DEPLOYABLE SHADE FOLDED, 4 REQ'D	29	SHADE, DEPLOYMENT ARC.
6	SIGNAL AND POWER CABLES	18	OUTSIDE ATMOSPHERE THERMIST.	30	GETTER RADIATION DETECTOR.
7	IMPULSE SOLENOID LEADS	19	DOUBLE ACTION SHADE DEP. MECH.	31	
8	SHADE ACTUATOR ROD	20	SUPPORT STRUCTURAL MEMBERS.	32	
9	HOUSING FOR ELECTRONICS	21	INSIDE ATMOSPHERE THERMISTORS		
10	ELECTRONIC PACKAGE	22	SPRING LOADED, SOIL THERMIST.		
11	SIGNAL PROCESSING & CONTROL CKTS.	23	CAPILLARY APPLICATOR.		
12	BUMP AND ISOLATION PLATE.	24	LIGHT TRANSPARENT WINDOWS		

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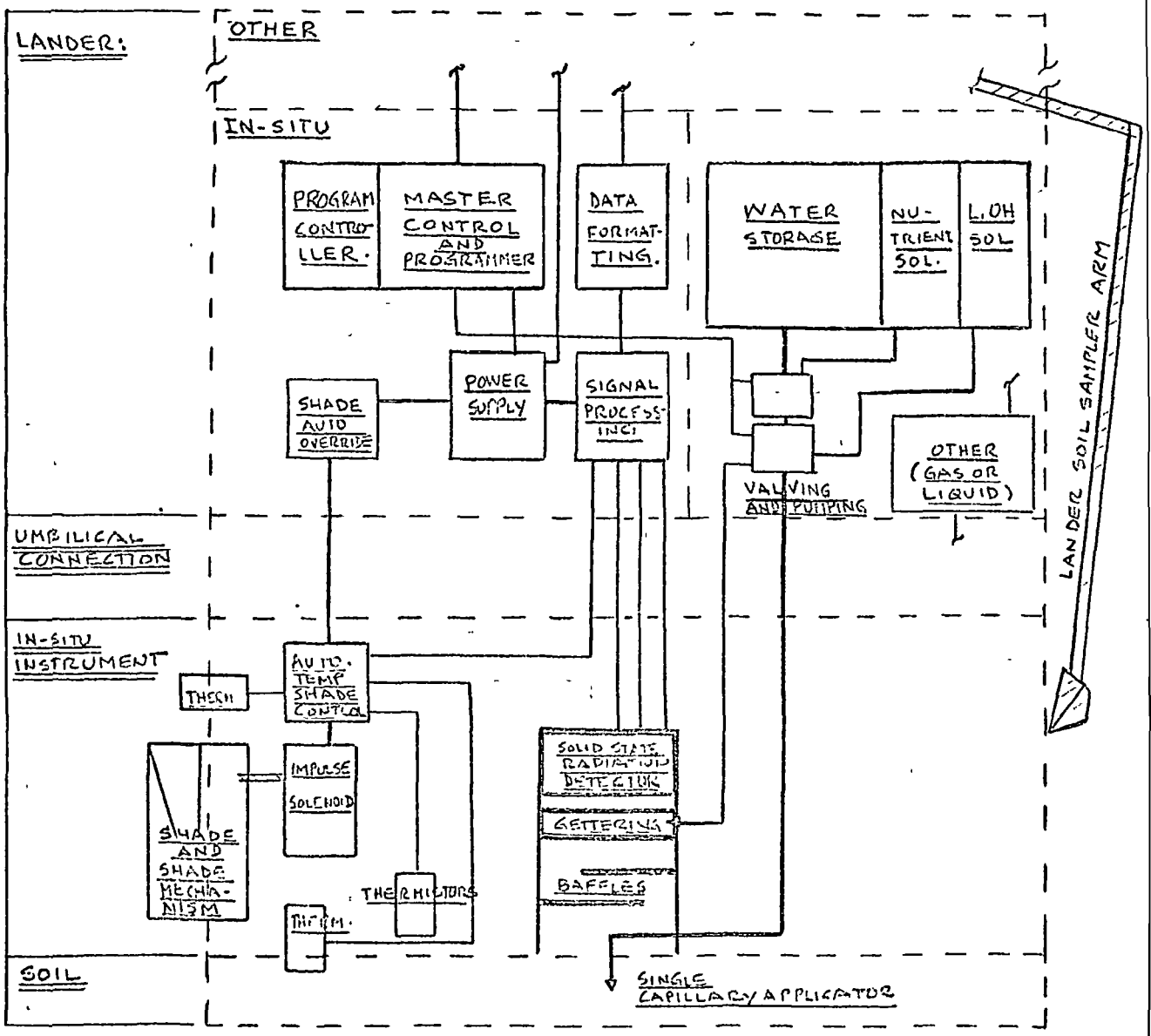

R. MOREJON

IN-SITU INSTRUMENT.

BLOCK DIAGRAM. LANDER SUPPORT EQUIPMENT.

BIOSPHERICS INCORPORATED, Rockville Maryland	Fig 76		
	12-69 Date	Init	Scale
NAS2-5360	In Situ Life Detection on Mars		

drical section. These arms serve to stabilize the assembly, to hold in place a soft, pliable, doughnut-shaped container (filled with a suitable liquid), and to support and secure the umbilical cord joining the instrument to the lander.

The cylindrical central section houses a light and a gas baffle system, a gettering section, a solid-state nuclear radiation detector, a pulse-actuated d-c solenoid, and a mechanical arrangement to deploy a four-section shade system for aid in controlling the temperature inside the experiment volume. The lower portion of the cylindrical housing supports a conical chamber and encloses the volume directly over the soil experimental volume. This conical section supports the inner periphery of the doughnut-shaped plastic container. The container serves to insure a better seal of the experimental volume by conforming easily to irregularities on the Martian soil surface.

Water is injected into the soil through a single capillary applicator held in position at its injection tip end by a bar which at the same time supports thermistors which register the temperature of the gas portion of the enclosed volume, as well as spring-mounted thermistors which monitor soil surface temperature. The spring mounting insures that, if they are not driven below the surface on a soft, powdery soil, at a minimum they will be held firmly against the soil surface. Thermistors are also installed on the under-

side of the support arms, away from direct sunlight, in order to register outside ambient temperature. The temperature data is monitored so that the liquid feed mechanism may be controlled at the proper ratio.

The actuator end of the deployable shades contains a double-action mechanism that holds or releases the folding shade sections while spreading or bringing together the supporting ribs at the same time. The hold-release action is accomplished each time by a single pulse to the actuating solenoid which therefore remains de-energized at all other times.

The umbilical cord leading from the instrument to the lander holds supply lines for water and gettering solution as well as required cabling and wiring for power and signal transmission to and from the radiation detectors, the thermistors, and the solenoid.

It is anticipated that deployment of the instrument and cable will be accomplished by the lander sampling arm after a suitable location within the area of sweep of the sampling arm has been selected by Earth command with the aid of the facsimile cameras.

5.0 FUTURE EFFORT RECOMMENDATIONS

Having demonstrated the feasibility of performing an in situ life detection experiment under simulated Martian conditions, the following recommendations are made:

5.1 Breadboarding

5.1-A Construction of a working model for testing under simulated Martian conditions.

5.1-B Determination of instrument characteristics and governing parameters.

5.1-C Optimization of the operation and detection efficiency of the breadboard instrument.

5.2 Prototype

Construction of a flight-oriented life detection system - implementation of the breadboard design in terms of NASA planetary mission hardware and instrument specifications, aerospace industry standards and practices, and specific NASA Viking mission requirements including size, shape, weight, materials, and pre-flight acceptance tests and procedures.

5.3 Viking Mission Experiment

Inclusion of the in situ life detection experiment and instrumentation as part of the NASA Viking Project for unmanned Mars lander 1973 and 1975 missions.

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As a final word, we would like to add that we do not anticipate any major problems for development and construction of a breadboard instrument. The electronics and mechanical components that would be used for programming, control, instrumentation, and data conditioning for the instrument would be standard off-the-shelf components in the industry. It is estimated that between four and six months would be required for construction of a breadboard instrument.